Lecture Notes in Networks and Systems 933

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Carlos Ferrás
Jorge Hochstetter Diez
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Preface

This book is composed of the papers written in English and accepted for presentation and discussion at The 2024 International Conference on Information Technology & Systems (ICITS'24). This Conference had the support of Universidad de La Frontera, Information and Technology Management Association (ITMA), IEEE Systems, Man, and Cybernetics Society, and AISTI (Iberian Association for Information Systems and Technologies). It took place in Temuco, Chile, January 24–26, 2024.

The 2024 International Conference on Information Technology & Systems (ICITS'24) is an international forum for researchers and practitioners to present and discuss the most recent innovations, trends, results, experiences, and concerns in the several perspectives of Information Technology & Systems.

The Program Committee of ICITS'24 was composed of a multidisciplinary group of 264 experts and those who are intimately concerned with Information Systems and Technologies. They have had the responsibility for evaluating, in a 'double-blind review' process, the papers received for each of the main themes proposed for the Conference: A) Information and Knowledge Management; B) Organizational Models and Information Systems; C) Software and Systems Modeling; D) Software Systems, Architectures, Applications, and Tools; E) Multimedia Systems and Applications; F) Computer Networks, Mobility, and Pervasive Systems; G) Intelligent and Decision Support Systems; H) Big Data Analytics and Applications; I) Human-Computer Interaction; J) Ethics, Computers & Security; K) Health Informatics; L) Information Technologies in Education; and M) Media, Applied Technology and Communication.

ICITS'24 received 389 contributions from 34 countries around the world. The papers accepted for presentation and discussion at the Conference are published by Springer (this book) and by RISTI and will be submitted for indexing by WoS, SCOPUS, EI-Compendex, and/or Google Scholar, among others.

We acknowledge all of those who contributed to the staging of ICITS'24 (authors, committees, workshop organizers, and sponsors). We deeply appreciate their involvement and support which was crucial for the success of ICITS'24.

Álvaro Rocha
Carlos Ferrás
Jorge Hochstetter Diez
Mauricio Diéguez Rebolledo

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Multimedia Systems and Applications

Efficiency Evaluation of Mobile Vision Transformers

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Abstract. Since the adoption of convolutional neural networks for computer vision tasks researchers have strived to adapt them to resource limited hardware. Recently, transformers have shaken up the world of natural language processing and also promise to do so in computer vision. However, their strengths are yet to be determined. In this paper we evaluate the efficiency of the most popular mobile vision transformer models in terms of latency and accuracy on ImageNet-1k and optimise their performance on a real-time facial landmark estimation task. Code and models publicly available at: https://github.com/pcr-upm/icits24_landmarks.

Keywords: mobile vision transformers · facial landmark detection

1 Introduction

The performance of mobile devices has grown explosively in recent years, while keeping the battery budget under control. Still, deep learning (DL) solutions, especially for computer vision (CV) tasks, require so much computational power that customised dedicated silicon is, in many cases, the solution used to make it plausible. However, not all devices have this extra hardware and it is not always the best option. Traditionally the most popular models were Convolutional Neural Networks (CNNs) specially conceived to save on computational resources so they are capable of carrying out in real-time some CV tasks, *e.g.*, MobileNetV2 [12] or MobileNetV3 [4]. However, architectures that leverage attention mechanisms, such as transformers, are increasingly being used in CV.

The success of the transformer models in CV comes with a higher computational overhead compared to CNNs. The self-attention operation is the main bottleneck, as seen in [8], due to its quadratic complexity wrt. the input length, which makes naive vision transformers comparatively slow on edge devices compared to mobile CNNs [16]. As a result, transformer architectures specifically tailored to mobile devices are emerging. The paradigm of these hardware- and power-constrained devices requires end-to-end solutions specifically designed to meet the computational needs without draining the battery.

In this work we evaluate and compare in terms of accuracy and efficiency the CNN baseline with some recently introduced architectures that leverage attention mechanisms specifically designed for mobile devices, denoted mobile Vision

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Transformers or mobile ViTs. We aim to determine both the efficiency of attention in constrained hardware in relation to CNNs, and its capabilities in relation to the currently available architectures. For this purpose, we consider an image classification task, the most common in the CV literature, and a facial landmark detection task, because of its importance in Human Machine Interaction (HMI) and because it will most likely benefit from the attention mechanisms used in transformers, given the prominent structure of the human face.

2 Related Work

The problem faced by mobile attention-based architectures is to design efficient models that effectively encode both, local processing, and global interactions. CNNs have designed biases that support the first whilst being very efficient at it, and transformers excel at learning long range dependencies [3]. Since plain attention is computationally very demanding, most designs employ a hybrid approach using both convolutions and attention.

MobileViT [9] and Mobile-Former [2] are the first models to combine convolutions and attention in mobile devices. The former joins sequentially the output of convolutions to the transformer, while the latter uses a parallel approach separating both, convolutions and attention (transformer). The latter is too costly to be effective, so the first approach will be the norm.

MobileViT V2 improves the performance by removing operations in the attention block and introducing a linear complexity self-attention [10]. Other approaches take advantage of matrix multiplication properties [1,8,13,18] or selectively attend the input [11]. All of them reaching consensus on limiting complexity to grow linearly wrt. to the input length and shifting the quadratic increase to the embedding dimension, where it is not an issue as it should be contained in length.

Regarding architectures, the main design choice is the use of multiple sequential stages. Each of them consisting in a number of convolution blocks (usually MobileNet blocks) followed, optionally, by a series of attention blocks, while spatial resolution is reduced in each of the stages by a factor higher than 2. The first attention block is strategically placed to take advantage of the features extracted by the convolutions. The reduction in resolution at each stage implies a smaller input the deeper we are in the model, allowing for a larger computational budget in the later stages, which is used to increase the depth or width of the proposed custom blocks or to use more of them [1,8–11,13,15,18]. We show in Fig. 1 an example of stage architecture.

In addition to these developments, [5,6,14] use Network Architecture Search (NAS) to extract subnetworks out of an efficient supernet in novel manners. [6] is the first to do it using an effective slimming mechanism, while [14] proposes to account for the gradient disparity in mobile sized networks, and tests performance directly in a mobile device to achieve and accurate search space.

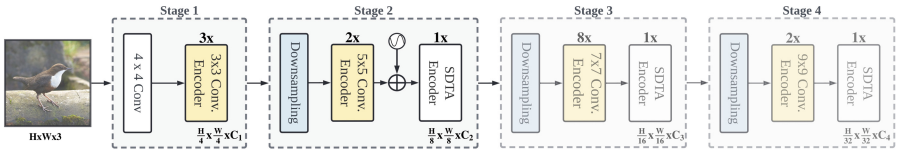

Fig. 1. Example of stage architecture design [8].

3 Experiments

In this section, we study the performance of relevant mobile architectures such as popular MobileViT and other more recent networks.

3.1 Database

The standard protocol to compare the efficiency among CNNs uses the ImageNet-1K data set. It spans 1000 object classes and contains more than 1M training images, 50K validation images and 100K test images.

Moreover, we also evaluate how ViT architectures perform in the face alignment task. For these experiments we use the WFLW data set [17] that contains 7500 images for training and 2500 images for testing, manually annotated with 98 landmarks. The test set is further divided into 6 subsets for different scenarios including 314 expression images, 326 large pose images, 206 make-up images, 736 occlusion images, 698 illumination images, and 773 blur images. We choose this data set since it includes large appearance variations in pose, expression and occlusion, which makes it extremely challenging, showing the benefits of a better architecture.

3.2 Evaluation Metrics

Ideally, we want a metric that takes into account the main limitations in mobile devices, *e.g.*, computing power, energy usage and latency, to name a few. In this way, Pan *et al.* [11] proposes the use of an energy-aware efficiency metric,

$$\frac{Score}{Latency \times Power} \tag{1}$$

where *Score* represents how well the model scores on a task (*e.g.*, accuracy), *Latency* the time required to perform inference on a single image, and *Power* the energy usage required for the inference.

Using this metric the higher the value the better the model performs under the aforementioned limitations. Equation (1) apparently fully represents the multi-objective metric search for efficient architectures on mobile devices. However, measuring power consumption on mobile devices is a complicated process with many pitfalls.

Alternatively, the number of operations used for inference on a single image (FLOPs) cannot directly translate into the latency and energy consumption on a specific device. This is due to several conditional factors dependent on the specific hardware design.

In this work, we measure the efficiency using the latency and score metrics, since power is difficult to evaluate especially on mobile devices which do not allow for consistent performance or power usage.

In Sect. 3.4 we use the *Accuracy* as the metric for the classification model which counts the number of correct predictions divided by the total number of predictions.

In Sect. 3.5 we use the common evaluation metric to quantify the alignment estimation error, regarded as Normalized Mean Error (*NME*). The NME computes the average euclidean distance L_2 normalized by d_i,

$$NME = \frac{100}{N} \cdot \sum_{i=1}^{N} \left(\sum_{l=1}^{L} \left(\frac{||\tilde{\mathbf{X}}_i^l - \mathbf{X}_i^l||}{d_i} \right) \right), \tag{2}$$

where N is the number of face images, L is the number of landmarks, and $\mathbf{X}$, $\tilde{\mathbf{X}}$ represent the estimated and ground truth landmark location respectively. For the WFLW data set, we report the results using as normalization, d_i, the ground truth distance between the outer eye corners (*corners*).

3.3 Implementation Details

In Sect. 3.4, we measure the latency with the Android mobile benchmark based on Pytorch[1] using a Google Pixel 4 device. To make each CNN compatible with the tool, we need to modify the architecture for a specific resolution and run the previous API to optimize the architecture for a mobile CPU. We use as input the whole image resized to 256×256 and 512×512 pixels to compare the importance of the resolution. We set the batch size to one image and we only use one CPU core for latency evaluation.

Note that in [5] every model is tested using an iPhone 12 with the Apple Neural Engine chip and performs roughly x5-x10 faster (in terms of latency) than an equivalent phone using its CPU (*e.g.*, Google Pixel 6). We do not have a device with that hardware to corroborate these results. Nonetheless, they seem to be inline with the results found in [10].

For the adaptation to the 2D face alignment task in Sect. 3.5, we replaced the last layer of each CNN with a fully connected layer with $L \times 2$ neurons (*i.e.*, x and y coordinates) being $L = 98$ the number of landmarks in the WFLW data set. We follow the same procedure training all CNN models. We set the batch size to 8, with an AdamW optimizer and MSE loss. We train from scratch each architecture for 500 epochs with an initial learning rate set to 10^{-4} and we always select the model parameters with lowest validation loss. We use as input the cropped input face at 128×128 pixels resolution in order to train faster

[1] https://pytorch.org/tutorials/recipes/mobile_perf.html.

the CNNs without a noticeable increment in the NME metric. Finally, we have performed data augmentation by applying to each training sample the following random operations: in plane rotation, scale, occlusions, illumination and blur.

3.4 Image Classification Results

In this section, we make fair comparisons among the most popular architectures based on efficient transformers, *e.g.*, MobileViT, which has not been completely explored so far in the literature.

We use a Google Pixel 4 device to compare the accuracy-latency trade off for an image classification task with ImageNet-1K images (see Fig. 2). On the one hand, ElasticViT [14][2] leads the efficiency chart, with EdgeNeXt [8] also providing real-time performance and the best accuracy metrics on the tested mobile CPU. On the other hand, Mobile-Former [2], using the most popular version with 214M parameters, shows the worst trade-off on its performance.

We also notice in Fig. 2 that there are two efficiency groups. The first containing all MobileViT versions [9,10,15], the other with more recent proposals such as EfficientViT [1], ElasticViT [14] or EdgeNeXt [8].

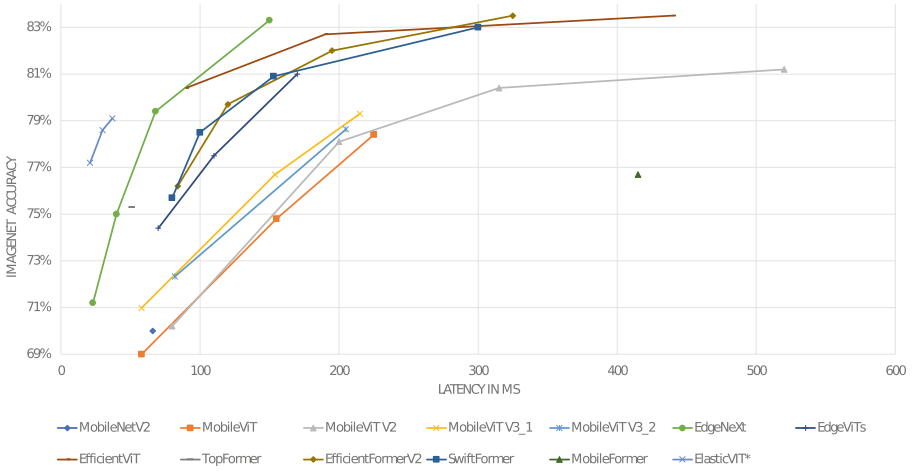

Fig. 2. Latency-accuracy comparison of mobile based architectures tested on a Google Pixel 4 using 256×256 images as input.

Additionally, for each architecture we also check how much slower the inference becomes when doubling the resolution of the input image (x4 increase in the number of pixels), (see Fig. 3). The results show that latency scales linearly with the resolution in all cases. Latency rises between 350% and 490% depending on the architecture. As a reference, MobileNetV2 has an increase of 450%.

[2] ElasticViT results are provided by the authors since code is not available and results cannot be reproduced.

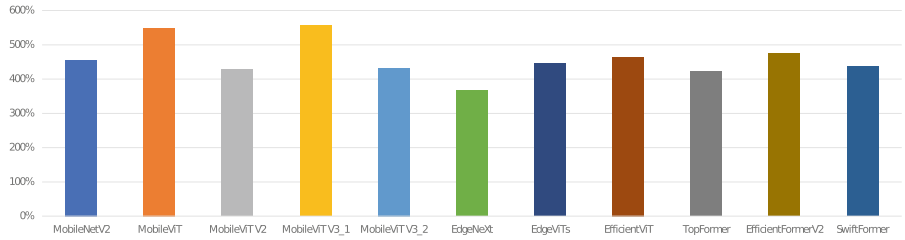

Fig. 3. Mean latency increase of processing 512×512 images against 256×256 input images on a Google Pixel 4.

3.5 Face Alignment Results

In this section, we focus on testing EdgeNeXt [8], the most efficient mobile ViT with public code, against MobileNetV2, our baseline, and ConvNeXt [7] CNNs for the face alignment task. These selected models have similar latency characteristics, around 60 ms approximately, on a Google Pixel 4 device. For the EdgeNeXt architecture we consider all four different configurations provided in [8], XXS, XS, Small and Base, to analyze how this task scales according to the ViT size. The overall model size mainly depends on the desired channel depth at each stage, and the number of blocks of each type used (see Table 1).

Table 1. Different EdgeNeXt configurations. *Si* represents the i-th stage, **C** is how many convolutional blocks there are at the start of the stage, **A** is the number of attention blocks at the end of the stage, and **D** is the channel depth for the whole stage.

Model	Params	*S*1			*S*2			*S*3			*S*4		
		C	A	D	C	A	D	C	A	D	C	A	D
EdgeNeXt XXS	1.3M	2	0	24	1	1	48	5	1	88	1	1	168
EdgeNeXt XS	2.3M	3	0	32	2	1	64	8	1	100	2	1	192
EdgeNeXt Small	5.6M	3	0	48	2	1	96	8	1	160	2	1	304
EdgeNeXt Base	18.5M	3	0	80	2	1	160	8	1	288	2	1	584

Our results in Table 2 show that MobileNetV2 is the fastest model, albeit by a small margin, and cannot match EdgeNeXt Small's NME. In addition, ConvNeXt scores better than EdgeNeXt Small (7.892 vs. 8.010), although it ties in latency.

We can find that the scores on each of the test subsets scale similarly with the overall score, no category is clearly improved by the use of our ViTs.

So what is the advantage of using these high-cost attention operations in resource-limited models if the latency is high and accuracy worse? To this end, we modify the EdgeNeXt architecture to try to better match our hypothesis in Sect. 3.6.

Table 2. Face alignment comparison of EdgeNeXt Small and Base against popular MobileNetV2, ConvNeXt and an Hourglass CNN using WFLW data set. The thick horizontal line divides the transformers from CNNs.

Model	Params	Latency (256^2)	Latency (128^2)	NME
EdgeNeXt L Small	5.341.612	85 ms	26 ms	8.010
EdgeNeXt L Base	18.040.952	175 ms	55 ms	**7.428**
MobileNetV2 L	**2.474.948**	**68 ms**	**16 ms**	8.417
ConvNeXt L Atomic	4.837.572	93 ms	26 ms	7.892
Hourglass	6.333.603	1 s 260 ms	–	4.972

3.6 Ablation Study

Given the results in the previous section Sect. 3.5, we want to analyze how different modifications on the ViT architecture affect its score and performance on the face alignment task. We show these results in Table 3.

We try six modifications to EdgeNeXt Small:

a. Modify self-attention to operate on the spatial dimension.
b. Spread the distribution of the convolutional blocks on the 4 stages (3,3,4,5).
c. Combine (a.) and (b.).
d. Increase the number of Attention blocks to (2,3,2,1) and reduce the number of convolutional blocks to one on each stage (1,1,1,1).
e. Increase even more the number Attention blocks to (5,4,2,1) and add an extra convolution block to the two final layers (1,1,2,2).
f. Eliminate all convolutional blocks with the previously tested (5,4,2,1) global block arrangement.

Table 3. Comparison of different EdgeNeXt Small configuration.

Model	Params	Lat (256^2)	Lat (128^2)	NME
(a.) Spatial Attention	5.3M	170 ms	33 ms	7.547
(b.) Convolution Spreading	6.9M	170 ms	31 ms	7.569
(c.) Both	6.9M	170 ms	33 ms	7.345
(d.) Att (2,3,2,1) + 1 Conv	3.5M	**68 ms**	**21 ms**	7.601
(e.) Att (5,4,2,1) + (1,1,2,2) Conv	4.7M	135 ms	41 ms	**7.073**
(f.) Att (5,4,2,1) No Convs	**2.6M**	80 ms	23 ms	7.624

To evaluate how the efficient attention used in EdgeNeXt affects the extraction of global features, we modified its attention mechanism, XCA, to bring back a more traditional spatial inference, by (a.) removing the transposition of matrices Q, K and V to operate on the spatial dimension. As can be seen in Table 3, (a) greatly increased latency and decreased the score, both similar to *Base* size.

On the other hand, in (b.) we modify the distribution of Convolutional blocks for a more evenly spaced feature extraction. To that end, we choose (3,3,4,5) convolutional blocks (instead of the (3,2,8,2)), with same global block arrangement (0,1,1,1) just one attention block on each stage except the first. Which leads to a very similar result to our latest test, (a.).

In (c.) we combine both (a.) and (b.). This solution keeps same latency while improving accuracy score over the *Base* size, resulting more efficient overall.

To gauge the actual effectiveness of attention blocks we start from the *XS* version for higher latency budget, leave only one convolution block in each stage, and (d.) add a number of attention blocks (2,3,2,1). This posed lower latency than the *Small* version while being closer in score to the *Base* size.

Focusing again on the *Base* size latency budget we add even more attention blocks (5, 4, 2, 1) in (e.), with an extra convolution in the last 2 stages, to extract more abstract features so that we enhance fine landmark positioning while piling up attention blocks at the input to retain broader landmark relationships. Compared to the *Base size*, (e.) has considerably lower latency with the lowest NME.

Finally, to show the capabilities of attention blocks on their own, in (f.) we removed all the convolutional blocks from the previous experiment, resulting in a model slightly less efficient than (d.).

Our goal has been to improve the results of both default EdgeNeXt Small and Base without increasing their latency, and we are able to achieve it by a considerable margin. First, we surpass EdgeNeXt Small with ablation (d.) in both latency 68 ms, 21 ms vs 85 ms, 26 ms and overall scoring 7.601 vs 8.010. As well as, secondly, notably improve EdgeNeXt Base with ablation (e.) also in both latency 135ms, 41ms vs 175 ms, 55 ms and average NME 7.073 vs 7.428.

4 Conclusions

Traditional self-attention, as used in ViT, degrades the efficiency in CV tasks. However, the use of more efficient attention mechanisms allows attention to be used earlier in the image processing pipeline, allowing for more efficient extraction of global relationships.

This global information is useful in certain tasks such as face alignment, where information from a given landmark provides information on the position of others. For this specific task, ConvNeXt has a better latency score than EdgeNeXt Small with close accuracy, which could lead one to believe that CNNs are "better" than ViTs. However, in our ablation study we show that by introducing small changes in the configuration of the EdgeNeXt architecture we achieve significant performance improvements.

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Online Shopping Experience: The Case of Zara

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Abstract. This study analyzes the online shopping experience on the website of Zara, a chain of clothing and fashion accessories stores for women, men, and children, to ascertain consumers' perceptions and opinions regarding: the perceived quality of the brand's website; social influence and recommendation; performance expectations; trust; satisfaction and brand loyalty. The analysis was carried out by implementing a questionnaire which obtained 293 responses from individuals aged 18 or over who had already placed at least one order on the website. After analyzing and processing the data, it can be said that both the perceived quality of the website and social influence and recommendation have a positive effect on performance expectations. Performance expectations have a strongly positive effect on consumer satisfaction and trust. It has also been shown that satisfaction has a positive impact on both consumer trust and loyalty. It was also confirmed that performance expectations and trust have no impact on loyalty and that trust does not mediate the relationship between satisfaction and consumer loyalty.

Keywords: Online Fashion Consumption · Shopping Experience · Consumer Satisfaction · Consumer Loyalty

1 Introduction

In recent years, online consumption has come to be considered a necessity and not just a trend, forcing companies to understand what needs to be improved in online shopping experiences. Consumers have begun to feel the need to get more involved with the brands they consume, to feel that they are part of the brand (Schmitt 1999), and, for this, it has become essential to adopt experiential marketing, with the aim of creating experiences that give consumers memories and increase the chances of them engaging with the brand and becoming loyal to it. Experiential marketing in the online market is essential because, as well as engaging consumers with the brand, it tends to allow consumers to repeat their purchase actions (Khoirunnisa & Astini 2021).

The study aims to analyze the process and experience of online shopping at Zara, checking whether the brand provides a good experience for consumers and also detecting possible changes or improvements to be made, in order to respond to the challenge of evolving according to the needs and preferences of consumers. Next, in Sect. 2, Theoretical Framework, a brief literature review is presented on the subject under study and

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the constructs that will be analyzed in the research hypotheses to be testes in this work. Section 3, Method, sets out the research hypotheses to be tested, the statistical techniques and procedures used, and a brief characterization of the sample under study. Section 4, Results and Discussion, presents and discusses the results of the data analysis and processing, with a view to testing the research hypotheses defined this study. Section 5, Conclusions and Implications, presents the conclusions, as well as the limitations of the study, and recommendations for future research.

2 Theoretical Framework

Over the years, not only has online commerce changed and progressed, but consumers have also changed and become more demanding. They are increasingly informed and communicate with each other and feel the need to be part of brands and get directly involved with them. To make this possible, experiential marketing was adopted, which provides experiences that connect consumers with the brand. These experiences, rather than satisfying and creating a relationship with consumers, aim to make the relationship between the two parts lasting and enable consumers to build loyalty (Smilansky 2009). Providing a good and differentiating experience in the online market is essential, given that there are so many brands in this market. According to the National Communications Authority (ANACOM 2021), one of the most consumed products in Portugal through e-commerce is clothing and footwear, which makes it interesting to analyze the online shopping experience of a fashion brand. To differentiate a brand and create a relationship with consumers, fashion marketing must be combined with experiential marketing, knowing how to adjust and adapt strategies to each specific market. Below is a brief review of the literature on the constructs that will be used to formulate the research hypotheses: perceived quality of the website, social influence and recommendation, performance expectations, trust, satisfaction, loyalty, and consumer income.

2.1 Perceived Quality of the Website

Ponte (2019) sees perceived quality as "a source of confident for consumers and financial results for companies, which should never be ignored." (pp. 27). Through this, consumers are better able to determine their online trust (Jadil, Dwivedi & Rana 2022), which is just as important, if not more so, in online commerce than in traditional commerce, as it is one of the most significant factors in the final purchasing decision.

There are several qualities that influence a consumer's purchase intention, such as information quality, service quality and system quality. If the actual quality is compatible with the quality previously perceived by the consumer, they will be satisfied and more likely to repeat the purchase. As such, it can be said that the perceived quality of a website is directly related to performance expectations (Rodríguez & Fernández 2017), because if you consider a website to have quality, you predict how well it will perform.

2.2 Social Influence and Recommendation

According to Baker, Donthu and Kumar (2016), the opinions of people close to consumers have a stronger influence on purchase intention than the forms of advertising

used. The recommendation of a product/service by these people can minimize consumer's perception of risk. Fetais et al. (2022) argue that online word-of-mouth is a credible and reliable form of advertising. However, according to Baker, Donthu and Kumar (2016), offline world-of-mouth tends to have more impact on people. For a consumer to start recommending and engaging with a brand, they have to reach a certain level of satisfaction or dissatisfaction, if that engagement is negative. From the moment a consumer receives several recommendations and feedbacks about a product, service or brand, they will automatically formulate a performance expectation about it.

2.3 Performance Expectation

Performance expectations is one of the main constructs that motivate purchase intentions (Venkatesh, Thong & Xu 2012). It is often built on prior knowledge about a brand, a product or a service. It is also considered one of the antecedents of consumer satisfaction (Johnson & Fornell 1991). If a consumer meets or exceeds their initial expectations about a product or service, they will leave the experience satisfied, if they do not meet these expectations, they will leave dissatisfied. When expectations are met, the consumer begins to trust the brand that has given them satisfaction. To do this, it is important that brands know their target audience's expectations well and that they don't promise anything they know they can't deliver, so as not to allow the consumer to form high expectations and then not achieve them. In this way, it can be said that performance expectations influence consumer satisfaction, which ultimately influences consumer loyalty.

2.4 Trust

Trust in an important element in a successful relationship between consumers and a brand, and it is essential when making a purchasing decision. Stefuryn (2018) characterizes trust as "a feeling of security for the consumer with a satisfactory brand that meets their consumer expectations" (pp. 34). Although online commerce is a growing reality, people still have a greater perception of the associated risk compared to traditional commerce. Lack of trust is one of the biggest problems and barriers to online commerce, so it is necessary to build a secure website and prove it (Flavián & Guinalíu, 2006).

Consumers achieve trust through experiences with the brand and based on third-part opinions and recommendations or through advertising (Venter 2016). Experiential marketing also has a positive and significant effect on product repurchase and the trust consumers feel (Khoirunnisa & Astini 2021).

2.5 Consumer Satisfaction

Kim, Jin and Swinney (2009) define consumer satisfaction as customer's perception of their shopping experiences. Oliver (1999) sees satisfaction as an act of consumption that satisfies some need, objective, or desire of the consumer, making them feel complete. Cardozo (1965) also treats satisfaction as a starting point for loyalty, as a satisfied consumer tends to repeat purchases, more easily accept new products from the brand and even create organic advertising about it to third parts.

Satisfaction is built when a consumer, on consuming a particular brand, meets or exceeds their initial expectations. If they don't, the consumer becomes dissatisfied and doesn't repeat the purchase. When a consumer has confidence in a brand and feels satisfied with it, they are more likely to become loyal to the brand (Hallowell 1996), which is why we can say that satisfaction influences consumer loyalty.

2.6 Consumer Loyalty

Loyalty in the online market is even more important than in traditional commerce. Lu, Marjerison and Seufert (2022) characterize loyalty as a relationship created with the customer, where involvement is required from both parts. According to Kim, Jin and Swinney (2009), this is a goal and a competitive advantage that all brands want to achieve.

Achieving customer loyalty means that the brand will have several advantages such as higher profits, reduced costs for acquiring new customers, lower price sensitivity on the part of loyal consumers and repeat purchase behavior (Hallowell 1996). However, it is not enough to satisfy consumers to achieve their loyalty, because, according to Mittal and Kamakura (2001), there are other factors external to the company that influence loyalty, such as age, gender, marital status, and the individual's income. However, without satisfaction, it is impossible for a consumer to become loyal to the brand.

2.7 Income

Income is a factor that moderates purchase intention and consumer decisions in the e-commerce environment (Tiruwa, Yadav & Suri 2018). In addition to the decision to make a purchase, income also influences other variables, such as the amount spent on online purchases. According to Saraiva (2012), as income increases, the amount spent also increases. The author also argues that there is no significant influence between income and frequency of purchase, however, Hernández, Jimínez and Martín (2011) state that a low income discourages the act of buying online, as those with a high income have a lower perception of risk. According to Neto and Figueiredo (2022), income positively moderates performances expectations but negatively moderates social influence. Also, according to Gonçalves and Sampaio (2012), high-achieving individuals tend to be less loyal to a brand. Therefore, income is considered a moderator between the relationship between satisfaction and consumer loyalty.

3 Method

The purpose of this research is to analyze the online shopping experience on the Zara website, by analyzing various constructs that may influence the experience (perceived quality of the website, social influence and recommendation, performance expectations, trust, satisfaction, and consumer loyalty) and by analyzing sociodemographic variables (age, gender, marital status, level of education, professional status and income). To carry out all this analysis, the following research hypotheses were established:

H1: The perceived quality of Zara's fashion website has significant impacts/effects on performance expectations.

H2: Social influence and recommendation have significant impacts/effects on performance expectations.

H3: Performance expectations have significant impacts/effects on consumer satisfaction.

H4: Performance expectations have significant impacts/effects on trust.

H5: Performance expectations have significant impacts/effects on consumer loyalty.

H6: Consumer satisfaction has significant impacts/effects on trust.

H7: Consumer satisfaction has significant impacts/effects on consumer loyalty.

H8: Trust has significant impacts/effects on consumer loyalty.

H9: Trust mediates the relationship between consumer satisfaction and loyalty.

H10: Employee performance plays a moderating role in the hypotheses presented (H1 to H9).

To achieving the study's objectives and test the research hypotheses defined, a questionnaire was drawn up to collect the Google Forms tool. The questionnaire was administered to individuals aged 18 or over who were in the habit of ordering online from Zara's website, or who had already placed at least one order. It was divided into eight parts: one dedicated to finding out the respondent's online consumption habits, the other six dedicated to analyzing the constructs selected to evaluate the online shopping experience: Perceived quality of Zara's fashion website, social influence and recommendation, performance expectations, trust, satisfaction, and consumer loyalty. In these six blocks, a Likert scale was used to respondents to evaluate each set of statements related to each of the six constructs (1 - Strongly disagree; 2 - Disagree; 3 - Neither agree nor disagree; 4 - Agree; 5 - Strongly agree). The last part of the questionnaire was dedicated to sociodemographic questions such as age, gender, marital status, level of education, professional status, and income. All the questions in the questionnaire were compulsory, and the participants' consent was obtained through an informed consent form before the research was carried out.

As for the statistical techniques used in the empirical research, the first step was to carry out an exploratory analysis of the data, using graphical representations. Among the statistical techniques used, it is worth highlighting the use of: i) Cronbach's alpha coefficient: assesses the internal consistency of each of the scales, in order to check whether the set of items referring to each of these scales help to adequately assess each of the constructs. This coefficient varies between 0 and 1, with values above 0.7 being acceptable (Cronbach 1951); ii) Kolmogorov-Smirnov test: an adherence test in which it is possible to ascertain whether the data comes from a population with a normal distribution, with a view to opting for parametric or non-parametric techniques (Smirnov 1948); and iii) Spearman's correlation coefficient: assesses the associations between two ordinal qualitative variables. This coefficient varies between -1 and $+1$ and provides information on the direction and intensity of variation between the two variables (Spearman 1904).

To evaluate the model proposed in this research, Structural Equation Modeling was used, using the Partial Least Squares algorithm (PLS-SEM), with the PLS-SEM 4.0 software, with the aim of explaining the relationships between the interdependent variables. The use of PLS-SEM indicates the relationships between the constructs and the items and also the relationships between the constructs themselves (Henseler et al. 2009).

The PLS-SEM methodology is divided into two parts: evaluation of the measurement model (relationship between latent variables and indicators) and evaluation of the structural model (links between latent variables) (Henseler et al. 2009). The measurement model makes it possible to see whether the variables chosen to measure the constructs are acceptable or not. The measurement model was assessed for internal consistency (Cronbach's alpha coefficient (α)) and reliability of the constructs (Composite Reliability), convergent validity (average variance extracted - AVE) and discriminant validity (*Fornell-Larcker* criterion) and *Heterotrait-Monotrait Ratio (HTMT)* criterion. The Composite Reliability gives us an estimate of the internal consistency of the constructs, values from 0.6 are already considered acceptable (Henseler, Ringle & Sinkovics 2009). The Average Variance Extracted (AVE) must be equal to or greater than 0.5, which means that the latent variable explains more than half of the construct (Wong 2019). The *Fornell-Larcker* criterion suggests that the square root of AVE in each latent variable should be greater than the other correlation values between the latent variables (Wong 2019), while in the *Heterotrait-Monotrait (HTMT)* criterion its values should be below the threshold value of 0.85 (Sallaku & Vigolo 2022).

Later, multigroup analysis (MGA) was then carried out to compare each of the estimated samples from one group with the other, thus testing whether there were statistically significant differences between the two groups for a given variable under study in the research hypotheses of the proposed model. The sample used in this study includes 293 valid responses, which differ slightly in terms of the gender of the respondents, as 243 (82.9%) are female and 50 are male (17.1%). The respondents' age range is between 18 and 78 years, with 82.7% of them in the 18–29 age group. As for marital status, most respondents (85.7%) are single. As for their level of education, 73.4% of respondents have higher education and, as for their professional situation, 47.4% are employees, while a significant proportion of the sample (28.7%) are students. In terms of income, the largest percentage (42%) earn between 750 and, 1199 € a month.

4 Results and Discussion

Initially, the internal consistency of the constructs was checked using the Cronbach's alpha coefficient (α), which found that all the values were above 0.7, proving that each set of items helps to adequately assess each of the constructs. It was also verified by testing the normality of the scores associated with each of the constructs under analysis, using the Kolmogorov-Smirnov test, that the hypothesis of normality in the data was rejected. Non-parametric tests were used in inferential statistics, namely Spearman's correlation coefficient (rs), to check whether there were significant correlations between the pairs of constructs under analysis, and all pairs of constructs were found to have a significant positive correlation ($p < 0.001$).

When assessing the quality of the measurement model using PLS-SEM, it was found that both the Cronbach's alpha coefficient (α) and the composite reliability (CR) were satisfactory, with values above 0.7. Also in the measurement model, convergent validity was assessed using the average variance extracted (AVE), and all the values were above 0.5, which proves the existence of convergent validity (Wong 2019). The *Fornell-Larcker* criterion was used to assess discriminant validity, which was found to exist when the

AVE square root value for each construct was greater than the correlation between the constructs (Wong 2019). Discriminant validity was also proven using the *Heterotrait-Monotrait (HTMT)* criterion, as all values were less than 0.85 (Sallaku & Vigolo 2022).

After verifying satisfactory reliability and validity, the structural model was evaluated based on the coefficient of determination (R^2) and using boostrapping in PLS-SEM, the significance of all the hypotheses under investigation was tested, and the results are shown in Table 1.

The variance explained in the endogenous constructs (R^2) varies between 0.401 and 0.557 (bold circles in Fig. 1). An analysis of the results shows that 55.7% ($R^2 = 0.557$) of the latent variable Satisfaction can be explained by the endogenous variable Performance Expectations (PE); the latent variable Trust can be explained by 48.4% ($R^2 = 0.484$) by the endogenous variables Performance Expectations and Satisfaction; the variable Performance Expectations is explained by 41.8% ($R^2 = 0.418$) by the variables Perceived Quality of Website (PQW) and Social Influence and Recommendation (SIR). Finally, the latent variable, Loyalty, is explained by 40.1% ($R^2 = 0.401$) by the endogenous variables, Performance Expectancy, Satisfaction and Trust.

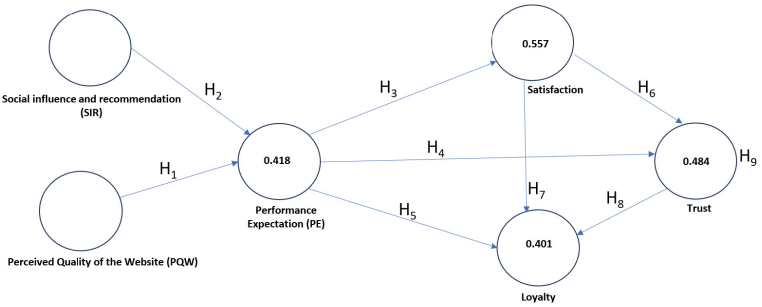

Fig. 1. Diagram of the final model used

The results obtained illustrate that the Perceived Quality of the Website (QPW) ($\beta = 0.544$, $p < 0.000$) has a positive effect on the Performance Expectancy (PE), thus supporting research hypothesis 1, which is in line with what is defended by Simão (2019, pp. 23), as he states that perceived quality "allows the product and its performance capacity to be valued, in terms of the need for satisfaction or the desire that is proposed". According to Salem and Alanadoly (2022), "… The overall perceived value to be positively related to the quality of the product, which influences consumer pre-purchase expectations. Quality, in this case, is an essential element in determining the value of a product leading to a positive buying behavior" (pp. 80). Also, according to Rodríguez and Fernández (2017, pp. 605), "perceived value, as the belief that buying the garment through an online website will be satisfactory and will add value to the transaction, is closely related to performance expectancy", there is a relationship between the two constructs.

H2 showed that Social Influence and Recommendation (SIR) ($\beta = 0.188$, $p < 0.000$) has a positive effect on Performance Expectancy. This validation is in line with what was

Table 1. Testing significance relative to the hypotheses under investigation

Hypothesis	Coefficient (β)	*t-value*	*p-value*	Decision
H1: PQW - > PE	0.544	10.656	0.000	Yes
H2: SIR - > PE	0.188	3.869	0.000	Yes
H3: PE - > Satisfaction	0.746	17.348	0.000	Yes
H4: PE -> Trust	0.471	5.750	0.000	Yes
H5: PE -> Loyalty	0.183	1.951	0.051	No
H6: Satisfaction -> Trust	0.270	3.396	0.001	Yes
H7: Satisfaction -> Loyalty	0.554	6.319	0.000	Yes
H8: Trust -> Loyalty	–0.110	1.534	0.125	No
H9: Satisfaction -> Trust -> Loyalty	–0.030	1.264	0.206	No

tested and supported by Loureiro, Cavallero and Miranda (2018, pp. 134), "Social Influence and Recommendation (as a second-order construct) by other fashion consumers are positively related to performance expectancy". Fetais et al. (2022, pp. 808) also argue that there is a relationship between Social Influence and Recommendation, in this case in the context of social platforms, and the expectations/perceptions that a consumer has in relation to a brand, "thus, within social media platforms consumers' discussion of a particular brand often builds on brand respect which is responsible about illustrating the brand's performance, which in turn enhances consumers' sense of trust, and builds brand reputation". However, according to the study by Loureiro and Amorim (2017), a relationship was initially predicted between social influence and recommendation and consumer performance expectations: "if a fashion consumer is enrolled and motivated by his/her peers, family and friends to use a fashion online platform and buy items from there, then the fashion consumer will tend to perceive the technology as more useful (higher performance expectancy), resulting in stronger usage intentions…" (Loureiro & Amorim 2017, pp. 84). However, these authors tested the hypothesis that there was a positive relationship between both constructs and this was not supported, which means that a significant relationship between the two constructs was not proven.

About research hypothesis H3, Performance Expectations ($\beta = 0.746$, $p < 0.000$) have a strongly positive effect on consumer satisfaction, thus validating H3. This confirmation is in line with what Johnson and Fornell (1991, pp.273) argue, "the primary antecedents of satisfaction are a product's perceived performance and the customer's expectations regarding that performance". In relation to H4, performance expectations ($\beta = 0.471$, $p < 0.0009$) have a positive impact on trust. According to Stefuryn (2018), trust is "a feeling of security for the consumer that the brand meets and responds to their consumption expectation" (pp. 34). In addition, the author states that trust is made up of three components, one of which is capacity, which "comprises the consumer's assessment of the brand's abilities and skills in fulfilling its promises in relation to their expectations" (pp. 35). Still in the results, in the 5th research hypothesis, it was found

that Performance Expectancy has no significant effect on Loyalty, which is not in line with what is stated by Loureiro, Cavallero and Miranda (2018, pp. 134), "performance expectancy leads to stronger usage intentions because consumer satisfaction with a service, or with technology, depends on their expectations of the performance of the or technology (Choi et al. 2011; Diep et al. 2016; Wang et al. 2016b). If a fashion consumer can use the technology provided on websites to perform what they had intended to do, then they will tend to feel satisfied, confident and it will be easier to communicate the positive experience to others".

Testing H6, it was found that Satisfaction ($\beta = 0.270$, $p < 0.001$) has a positive impact on Trust. Venter (2016), while not proving it, also assumes a relationship between the two constructs "while it can be said that consumers that have positive brand experiences tend to also have strong trust in the brand, it is not yet fully understood whether it is the experience that develops the trust, or if the initial trust that consumers place in a brand tends to affect their perceptions of their experiences with the brand". H7 showed that Satisfaction has a positive impact on Loyalty, a correlation previously validated by Hallowell (1996). As for H8, it was found that Trust has no significant effect on Loyalty, which is not in line with Reichheld and Schefter (2000), "to gain the loyalty of customers, you must first gain their trust. This has always been the case, but on the Web, where business is conducted at a distance and risks and uncertainties are magnified, this is truer than ever".

As for H9, it was tested and proven that Trust does not mediate the relationship between Satisfaction and Consumer Loyalty, something assumed by Venter (2016):

Table 2. Moderating effect of income on the variables under study

Hypothesis	Path Coef. (≤1199 €)	Path Coef. (≥1200 €)	Path Coef. Differences	p-value Henseler's MGA	Supported hypothesis
H1: PQW -> PE	0.438	0,690	–0,251	0,012	Yes
H2: SIR -> PE	0.266	0,084	0,182	0,062	No
H3: PE -> Satisfaction	0.732	0,774	−0,041	0,612	No
H4: PE -> Trust	0.494	0,426	0,068	0,657	No
H5: PE -> Loyalty	0.128	0,225	−0,097	0,627	No
H6: Satisfaction -> Trust	0.245	0,316	−0,071	0,636	No
H7: Satisfaction -> Loyalty	0,570	0,598	−0,029	0,846	No
H8: Trust -> Loyalty	−0,052	−0,215	0,163	0,310	No
H9: Satisfaction -> Trust -> Loyalty	−0,013	−0,068	0,055	0,295	No

"trust is a predictor of loyalty where, if a customer's trust is established, consumers are likely to be satisfied.". Finally, about H10, the multi-group analysis showed that the income of individuals only has a moderating role among the hypotheses tested previously (H1 to H9) in the case of hypothesis 1.

According to the results obtained, shown in Table 2 in the case of hypothesis 1, the relationship between Perceived Quality of Website (PQW) and Performance Expectancy (PE) has a stronger impact on individuals with a higher income ($\beta = 0.690$), compared to those with a lower income ($\beta = 0.438$).

However, the results indicate non-significant differences between the other trajectory coefficients and relationships between the two defined groups (group 1 - income of 1199 € or fewer; group 2 - income of 1200 or more), regarding hypotheses 2, 3, 4, 5, 6, 7, 8 and 9.

5 Conclusions and Implications

The purpose of this research was to analyze the online shopping experience of the Zara brand by evaluating several essential components, such as Perceived Website Quality, Social Influence and Recommendation, Performance Expectancy, Trust, Satisfaction and Loyalty. Along with these components, some sociodemographic variables were also analyzed.

To carry out this analysis, a literature review was first carried out on the subject under study, to support the development of the research hypotheses. A questionnaire was then drawn up to collect the data needed to use quantitative research methods. This questionnaire was applied to individuals aged 18 or over who were in the habit of shopping online at Zara, or who had already made at least one purchase. Analyzing the sociodemographic characteristics of the selected sample, the majority are between 18 and 29 years old (82.7%), i.e., they are young, single and belong to generation Z. In terms of educational qualifications and professional status, the majority have higher education and are employed. In terms of income, most respondents earn between 750 and, 1199 € a month.

Regarding the results obtained through data analysis, H1 showed the very positive impact of the perceived quality of the website on performance expectations, something already advocated by Salem and Alanadoly (2022) and Rodriguez and Fernández (2017). When evaluating H2, it was found that Social Influence and Recommendation have a positive effect on Performance Expectancy, which is in line with what was supported by Loureiro, Cavallero and Amorim (2017), so there is divergence between the different results. In H3, there was a significant positive effect that Performance Expectancy has on Consumer Satisfaction, like what was argued by Johnson and Fornell (1991). The positive impact of Performance Expectancy on Trust was proven by testing H4, a relationship already understood by Stefuryn (2018). Regarding H5, it was found that there is no significant impact of Performance Expectancy on a consumer's Loyalty, which is not in line with what Loureiro, Cavallero and Miranda (2018) stated. Testing H6 proved the positive effect of Satisfaction on Trust, an effect supported by Venter (2016). Testing H7 showed that Satisfaction has a strong positive effect on Loyalty, a correlation already validated by Hallowell (1996) and defined by Oliver (1999). It was also proven that Trust

has no significant impact on consumer Loyalty, by testing H8. This result is not in line with what was stated by Reichheld and Schefter (2000), Kim, Jin & Swinney (2009) and Khoirunnisa and Astini (2021). Another result was that Trust did not mediate the relationship between Satisfaction and Loyalty, something predicted and defended by Kim, Kin & Swinney (2009) and Venter (2016). Finally, through the multi-group analysis, H10 was tested, and it was found that income does not play a significant moderating role in the hypotheses previously tested (H1 to H9).

One of the main and most important contributions that this research makes to the literature is that it presents a complete analysis of a brand's online shopping experience. Unlike many studies that only analyze a few constructs individually, this research, in addition to analyzing several constructs, interconnects them in an innovative way, analyzing the overall shopping experience on Zara's website. In addition to analyzing the importance of each of the selected constructs, this study provides a holistic understanding by interconnecting all the constructs. Thus, this research can serve as a basis for other studies on the online shopping experiences of other brands.

In addition to the important contribution of this research to the literature, it is also possible to consider practical implications for the Zara brand and for other fashion brands that sell through the online channel. It is essential for a brand to have knowledge and awareness of consumers' needs and preferences when shopping online, which, despite already being such a widely used form of commerce, still generates some uncertainty. It is also important for each brand, and not just Zara, to understand how it can improve or even differentiate its online shopping process to provide a good experience for its consumers, so that they are satisfied and more likely to become loyal to the brand. By interpreting the results obtained in this research, brand managers can understand what needs to be prioritized in online shopping experiences.

Another valuable contribution is the provision of support tools for managers of fashion brands that sell online. It is recommended that they invest heavily in customer support lines, bearing in mind that these should be simple but dynamic, providing more direct contact with the consumer and quick resolution of possible problems. For example, a website's chat/virtual assistant should be simple and able to provide extra support to the consumer, in addition to the information already on the website. By improving this service, consumers will be more satisfied and trust the site even more, thus increasing their online purchases. Another recommendation, particularly for managers of the Zara brand, is to differentiate their online service from competitors. To do this, you need to know your target audience well and their needs and preferences. There are various techniques that can help with this differentiation, such as: the accumulation of points on orders; discounts for repeat customers on the website; customer cards with advantages, among others.

In this way, the results of this study make an important contribution to the literature on this subject and to Zara's marketing managers, as well as to other similar fashion brands, pointing out recommendations on the aspects that should be improved to meet the expectations, needs and preferences of contemporary consumers.

Regarding the limitations found in this study, the first relates to the small sample size and the predominance of the 18–29 age group. It would therefore be more cautious to generalize the results obtained only to younger consumers, the so-called digital natives

belonging to generation Z. Another limitation relates to the discussion of the results, because although there are a significant number of studies about the online shopping experience and the variables analyzed, few assess the overall shopping experience. It is also suggested that brand managers be interviewed to understand the brand's internal point of view on the whole experience process they intend to provide.

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Virtual Reality as a Tool for the Reconstruction and Dissemination of Cuenca's Cultural Heritage: Cases of the "Puente Roto" Bridge and the "Cornelio Merchán" Building

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Abstract. This article presents the design, development and evaluation of two serious games in virtual reality, using the tools Unity and Blender, and the platform Firebase for the database management. The games aim to promote the learning of the history of two historical-cultural places of the city of Cuenca-Ecuador, through immersion, interaction and feedback. The application shows two scenarios, such as: the Puente Roto Bridge, which includes an animation of its destruction and, a historical and destroyed building more than 60 years ago, called Cornelio Merchán, and that was part of the historical legacy of the Salesians in Cuenca. The programming part focuses on the implementation of the logical, graphical and sound components of the games, as well as on the integration with Firebase for the storage and query of the data of the users, the scenarios shown, the scores and achievements. The languages C# and JavaScript are used for the development of the scripts in Unity, and the libraries Firebase SDK and Firebase Auth are used for the connection with the database. The algorithms and data structures used for the operation of the games are described, as well as the challenges and solutions found during the process. The evaluation of the games is carried out through an experimental study with 10 students, who play both games and answer a pre- and post-test questionnaire. The results show that the games are effective to improve learning and motivation of people, as well as to generate a positive and satisfactory experience.

Keywords: cultural heritage · virtual reality · ICT · serious games · SDK

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1 Introduction

Virtual reality (VR) is a revolutionary technology that has opened up new possibilities in various fields of modern society. Cultural reconstruction and dissemination are areas in which its use has been widely studied. According to [2] VR provides users with an immersive experience that transcends time and distance. At this point, it is important to highlight VR's ability to provide a complete sensory experience in cultural reconstruction and dissemination. It contributes to the preservation of cultural heritage. And it allows to study and analyze objects and places without putting them at risk [5].

Accurate and detailed virtual models serve as digital backups [13] for the knowledge of new generations and the rescue of cultural memory as a social symbol for the preservation of identity. In the words of [15], the lack of appreciation and preservation of ancestral culture has a negative impact on the development of cultural tourism.

Although the era of information, communication and technological innovation has had an important impact on cultural rescue and the dissemination of culture, it is important to note that not all aspects have been fully addressed [16]. Thus, it is undeniable that digital technology has generated great opportunities for the preservation, dissemination and access to culture in innovative ways. However, there are still challenges and areas that require attention and continued development.

Much of the history of museums, churches and ancient buildings today have conservation protocols supported by technology, through audiovisual records and other tools. However, problems such as accessibility and the dissemination of the heritage legacy of these spaces have not been solved. This is due to the fact that not all people have the possibility to physically travel to these places to get to know them, explore them and disseminate their essence [4].

This study is based on the need to disseminate and reconstruct the cultural heritage of the city of Cuenca, located south of the Ecuadorian Andes. Cuenca, known as the Athens of Ecuador for its flamboyant colonial architecture, its cultural diversity and its historical contribution to the arts, sciences and Ecuadorian literature, contains in its streets, buildings and patrimonial houses a cultural legacy, for which its historical center was declared Cultural Patrimony of Humanity by UNESCO in 1999. It is visited by thousands of tourists from all over the world, who can enjoy the architectural heritage that the city offers. However, the history and culture it represents has been relegated to past generations, which compromises the cultural identity of Ecuadorians and the sense of local belonging.

Consequently, the present study aimed to design, develop and evaluate a serious game in virtual reality for the knowledge of two historical places in the city of Cuenca: the Cornelio Merchán building, an imposing building of Italian architectural style destroyed by fire in 1959 [6], and the Puente de Todos los Santos Bridge, known today as The Puente Roto (Broken Bridge). A stone structure that connected the two banks of the Tomebamba River, partially collapsed in 1950 as a result of the flooding of the river.

For the purposes of this research, at the terminological level, the definition of serious games is assumed to be video game applications designed for educational, training or entertainment purposes. It is also recognized that the greatest potential of serious games is given by the possibility of combining elements of entertainment and pedagogical objectives in order to teach, entertain or simulate real situations in an interactive and attractive way.

The following are the main results of studies related to the use of VR for the dissemination and reconstruction of cultural heritage.

Internationally, there are multiple studies on the use of VR for the dissemination of cultural heritage. Their implementation has allowed visitors to explore and learn about cultural heritage in an immersive and educational way. The following are the main results of studies related to the use of VR for the dissemination and reconstruction of cultural heritage.

The research developed by [11] with the aim of reconstructing the heritage of the medieval St. Catherine's Church located in Killybegs- Ireland, proposes the creation of a virtual museum for the preservation of digitized heritage objects and artifacts. They propose a mixed methodology to transport people into past worlds, enhancing their experience and, of course, their understanding of cultural heritage. Also, [2] proposes a generative method with the ability to improve the levels of interoperability that represent HBIM models for the generation of immersive environments based on the main game engines, such as Unreal Engine. They employ advanced modeling techniques centered on Non-Uniform Rational Basis-Splines (NURBS) algorithms, with the ability to authentically represent the selected artifacts and an open source visual command structure sequential structure language targeted for the game (blueprint for game engine).

The authors [14] set out to determine the potential of the World-as-Support interaction paradigm, based on the projectivity of (AR). They present the design of a virtual heritage model using (AR) with a projective character on an air-raid shelter that was built during the Spanish civil war period and currently belongs to the Museum of History of Barcelona. They highlight the potential of this approach for learning about historical artifacts and cultural heritage. They evidence the benefits of complementing the guided tour by using projective AR to explore different layers of the learning experience and to include collaborative activities based on representations.

Likewise, [1] argues that museums constitute an inexhaustible source of knowledge and contribute to the strengthening of cultural identity and heritage. It analyzes the use of AR in museums for the preservation of the cultural identity of extinct ethnic groups. The research is based on the identification through AR of archaeological pieces and artifacts of the Zenú ethnic group in Colombia. The project shows that the visualization of Zenú archaeological objects through augmented reality enriches the experience of museum users and the preservation of indigenous culture.

The authors [7], analyze the use of new visualization techniques including immersive virtual reality and develop Agnano RiVive. An immersive VR application created for the Museum of Preclassical Civilizations of Southern Murgia

in Ostuni. They seek to preserve the findings of the Archaeological and Naturalistic Park of Santa Maria di Agnano; giving the opportunity to users to not only explore and interact with ancient manufactures. The game guides the user to help with the burial ritual of Ostuni I, the world's oldest mummy found at the site.

On the other hand, [12] analyzes the capacity of virtual reality (VR) as a form of video game to educate students about the cultural heritage of rock art. They developed a virtual reality prototype for creating rock art that combines oral storytelling and the display of rock paintings in a digital cave. The results show how emerging technologies contribute to the preservation of intangible cultural heritage.

Within this framework, [9] agrees with previous research by stating that VR offers great potential for the development of video games, especially the so-called serious games, which beyond entertaining, have educational, formative and even therapeutic purposes. In addition, they promote the motivation and the permanent interest of the users towards knowledge [10], so they are assumed as an interactive and innovative way to learn [3]. Among the contents that [8] believes can be taught using serious games as a learning resource are those related to the learning of history and culture.

The studies analyzed show the potential and benefits of virtual reality as a resource for the dissemination, preservation and reconstruction of cultural heritage at the international level. However, the documentary review shows the absence of virtual reality applications focused on cultural tourism and learning about local history and culture.

2 Methodology

The development of the research considered the use of theoretical and empirical methods for the collection of information, as well as for the design of the game and its validation. Data collection for the development of the project was carried out physically and by consulting primary and secondary sources.

The use of theoretical and empirical methods allowed obtaining solid and reliable results. The theoretical methods employed included a review of the literature and theories in order to define the conceptual framework of the research. As for the empirical methods, experimentation and data collection through the use of the questionnaire and the survey were used. The latter made it possible to support and validate from a practical point of view the potential of VR for the dissemination of cultural heritage.

The Unity and Blender tools and the Firebase platform were used to create the game. In addition, the programming languages C# and JavaScript were used to create the scripts that control the logic, graphics and sound of the game, as well as the Firebase SDK and Firebase Auth libraries for the connection with the database.

Scripts developed in C# and JavaScript are essential to enhance the interactivity of the game. Through expert programming, we were able to code precise

elements, such as the movement of doors, rivers and solid objects. This ensured that players experienced smooth and realistic interaction with the virtual environment, adding depth to the gaming experience.

The project adopted an agile development approach, conducting frequent user testing to gather valuable feedback. This feedback loop allowed iterative improvements to be made to the game in real-time, ensuring that it is always at the forefront of quality and user experience. Based on this, new dimensions of user interaction with the virtual environment have been explored, such as the incorporation of an intuitive user interface that allows players to customize their gaming experience, adjust settings, and access relevant information in a simple and accessible way. This ensures enhanced game playability and provides greater control over the experience.

From the technical point of view, the tools Unity and Blender, which are 3D video game design and development programs, and the Firebase platform, which is a database service in the cloud that allows storing and consulting user data, levels, scores and achievements of the game, were used to create the game. In addition, the programming languages C# and JavaScript were used to create the scripts that control the logic, graphics and sound of the game, as well as the Firebase SDK and Firebase Auth libraries for the connection with the database.

The project was carried out from the structuring of four sequential phases, comprising the study of the basics of VR, history and culture of places in the city of Cuenca and analysis of the design tools Unity and Blender; the selection and download of data collected for the preliminary design in virtual reality, following the model of structure design; the design and development of the business layer of the virtual environment, consisting of user management, audio, video, text, maps, and allows the development of a database of learning assessments. A sentiment analysis of the use of the virtual environment is also elaborated. All these data will be stored in the cloud through Firebase. Finally, the functionality and interaction of the users with the virtual environment of the historical sites is tested. Figure 1 shows the integration of the user layer and the presentation layer of the application.

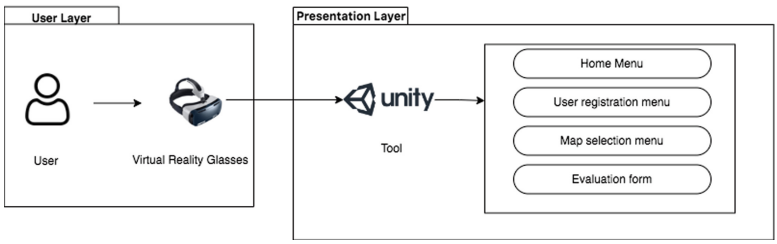

Fig. 1. User and presentation layers

The split network structure was structured in three parts. As seen in Fig. 2. First, the user is presented using the virtual reality glasses or goggles, which are

connected to a computer (server) via a USB cable or wirelessly. This computer hosts the virtual reality application. Once the process that allows the application to function is completed, the user's information is saved together with the results of the evaluation. This information is stored in a data server deployed in the cloud (Firebase). Once this process is completed, the server confirms to the user that their data and evaluation results have been successfully saved. VR is supported by components or peripheral devices that enable the immersive sensation and determine the user experience. Among the main VR peripheral devices are virtual reality glasses or lenses.

Fig. 2. Local (hybrid) system deployment diagram

3 Results

The creation of our game has embraced the cutting edge of technology and has implemented numerous innovations in key aspects that will be detailed in this section, such as the use of the Unity and Blender tools, the Firebase platform, as well as the C# and JavaScript programming languages.

The development of the models was carried out by means of the Blender tool. One of the developed models is shown in Fig. 3. This model shows the complete structure of the broken bridge, with all the arches and the descent to 12 de abril street in the city of Cuenca.

According to the characteristics of the project, it was decided to develop each model individually, with the purpose of allowing specific modifications in case they were necessary and to maintain an appropriate development control in each one of them. This approach allows for a higher level of flexibility and adaptability in the model development process. By approaching each model separately, it facilitates the identification and management of possible changes or improvements required in each of them, without affecting the integrity of the rest of the models.

In the case of the model of the Cornelio Merchán building that was once located in María Auxiliadora Park, through the collaboration of a student of the Multimedia Design Career of the Salesian Polytechnic University, it was possible to obtain greater detail of the textures of the emblematic building, as can be seen in Fig. 4.

The following link shows how the virtual reality application works.

Fig. 3. Modeling of the Puente Roto bridge.

Fig. 4. Modeling of the Cornelio Merchan building

Once the models are designed, they are exported in FBX format for manipulation in Unity 3D. This allows to take advantage of the capabilities of the tool and ensure a smooth integration of the models in the application. During this phase, the Unity 3D project was prepared to recognize the controls of the oculi. We also worked on the terrain or area, where the models made in Blender were placed. In this section we tested the connectivity of the database, login with its respective code, navigation menu between scenes with its respective code and the project survey. For data storage, the Google Firebase database was used because it is a non-relational database and allows to see the changes in real time.

The evaluation of the game was carried out through an experimental study, which considered a non-probabilistic purposive sample of 100 students from the Salesian Polytechnic University of the city of Cuenca who played the game and responded to a pre-and post-test questionnaire. Prior to the start of the game, the users were informed of the objective of the application and the instructions about the game. The questionnaire applied before starting the game showed little knowledge of the users about the history of the Cornelio Merchán building and the Broken Bridge, even though most of the participants are residents of the city of Cuenca. The results showed that the game was effective in enhancing students' learning and motivation, as well as generating a positive and satisfying experience. Based on the tests conducted and the results obtained, the pedagog-

ical implications and possibilities for improvement and expansion of the game are discussed.

During the tests, a questionnaire with mathematical calculations was incorporated to provide the user with a grade and feedback on incorrectly answered questions. This function enriched the user experience by providing an interactive and formative evaluation, encouraging learning and continuous improvement in the use of the application. The questionnaire with mathematical calculations is used as a methodology for the evaluation of the scope of the application in terms of the level of understanding of the contents on cultural heritage. Such methodology is assumed because it provides a solid and reliable approach not only in the assessment of the results but also in the analysis of the data and the support of the conclusions of the research. In correspondence with the objectives set for the development of the research, the use of this methodology is determined by the levels of reliability it generates to assess the results objectively. Compared to other methods such as qualitative observation, mathematical calculations do not generate biases in the research and provide accurate data on the results obtained.

In addition, a user satisfaction survey was conducted, through which 91.7% of the respondents stated that the game is effective as an educational tool about the city's cultural heritage. Meanwhile, all respondents agreed that virtual reality can be an effective tool for learning about historical events. In order to ensure the proper and functional fulfillment of the virtual reality application, a template was used to provide a guiding and coherent structure for its development, facilitating the integration of the necessary elements and ensuring consistency in the design and functionality of the application. Its implementation allowed a more efficient management of the project and a higher quality in the final delivery of the product.

As part of the analysis of the application, surveys were conducted to evaluate both the level of learning and the functioning of the application. Similarly, a survey was conducted to measure user satisfaction in using the virtual reality application, resulting in 50 percent excellent and 50 percent good. In the learning results, 50% of the participants were able to acquire knowledge satisfactorily. These results support the effectiveness of the video game as a learning tool and highlight its ability to generate a positive impact on the teaching-learning process.

4 Discussion

The virtual reality project creates an immersive and educational experience that allows users to explore and learn about two historical monuments of great importance to the city of Cuenca, Ecuador. Like the research developed by [11], it seeks to reconstruct the heritage through a methodology that transports people to the past for the understanding of its history.

The study and its results coincide with the interest of [2,12] in rescuing the intangible values of historical monuments declared by UNESCO as cultural heritage of humanity.

As posited by [14], collaborative activities on the basis of elaborated representations promotes a greater understanding of historical content that generates emotional engagement and critical thinking on the part of visitors. Corresponding to [1], it is assumed that VR technology, provides a unique experience for users, allowing them to learn and explore about culture and history in an exciting and educational way.

5 Conclusions

Virtual reality has proven to be an innovative technology for the rescue of cultural heritage. Although its use has been tested in different historical monuments internationally, the documentary review shows the absence of research developed on the use of virtual reality for the dissemination of cultural heritage in the city of Cuenca, Ecuador.

The design and development of the virtual environment was carried out in a comprehensive manner, including user management, audio, video, text and maps. The resulting application not only promotes tourism and the history of the city of Cuenca, but also offers a learning assessment, which enriches the user experience and encourages greater engagement with the content.

The results obtained through this application indicate an average learning rate of 53.33%, which corroborates the viability and effectiveness of the proposed system in various educational settings. This finding highlights the effectiveness of the application as a learning support tool and supports its potential to foster knowledge development in a meaningful way. The functional tests carried out on the virtual environment, specifically in the Puente Roto and the building of the Instituto Salesiano de Artes y Oficios Cornelio Merchán Tapia, demonstrated its correct functioning and its capacity to offer an immersive and educational experience to users.

By recreating these historical monuments in a virtual environment, it can provide an effective tool for the preservation of the historical and cultural memory of the city and encourage education and interest in local history and culture. The use of virtual reality for the reconstruction and dissemination of cultural heritage generates a greater awareness of the importance of preserving cultural heritage for future generations, so virtual reality technology emerges as an innovative and effective tool to recreate these lost historical monuments in an immersive and realistic virtual environment.

As a recommendation, it is important to ensure the compatibility of the application with various platforms, which will considerably expand its scope and provide the possibility of resolving possible problems more quickly and effectively. Future research can focus on analyzing the technical, cultural and ethical challenges of using virtual reality for the dissemination and reconstruction of cultural heritage.

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Lextutor Program as a Tool to Teach ESL Vocabulary

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Abstract. There is a growing trend among educators to embrace novel technology to enhance English language acquisition. It is imperative to be updated with new trends in learning, apart from the traditional methods. The study aims to have a positive impact on the way teachers introduce new vocabulary by equip-ping them with innovative and effective approaches to teaching vocabulary through corpus analysis and the use of technology. It will enable students, from beginners to advanced, to reach a real internalization of new words to get a deeper global understanding of the language. Nowadays, there are a significant number of programs freely available on the Web that offer us resources for language learning. This research focuses on vocabulary acquisition by applying a software called Lextutor.ca that displays several tools for linguistic analysis and learning English as a second or foreign language. This program works by man-aging corpora for academic purposes. It will allow users to have access to the storage corpora to obtain the most- relevant vocabulary of the language studied and practice it with contextualized exercises. For this purpose, six tools were selected due to their practicality and easy handling.

Keywords: Corpora · Lextutor program · Vocabulary Acquisition

1 Introduction

To manage a second or foreign language implies handling some macro-skills (reading, writing, listening, speaking) that allow the speaker to communicate with others without much effort, and vocabulary acquisition has an imperative role in developing all of them. To support this idea, McCrostie (2007) [1] remarks on the importance of possessing vocabulary knowledge to demonstrate communicative competence when producing and receiving information.

It is important to use words accurately, as they often have multiple meanings. In the field of second language teaching, it is necessary to be careful when using the term "vocabulary" and to clarify carefully what we are referring to.

Learning ESL vocabulary is not a mere process of memorization, it is necessary to have a certain hour of practice to know the collocation, spelling, pronunciation, and appropriateness of a word (Nation 2010) [2]. To get this grade of word appropriacy, the learner should meet the words in several counters and consider it relevant to develop the

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macro-skills. For this reason, a variety of exercises should be applied to help students internalize the word's meaning.

On the other hand, acquiring a new language requires having an acceptable range of vocabulary. It does not mean that the learner needs to know superfluous words because not all of them are used in daily life. Therefore, according to Webb and Nation (2017) [3] a learner considers a word as relevant based on the frequency that it occurs in a language. As Nation & Waring (cited by Zakian, et al. (2022) [4] concluded in their research, it is necessary to know 3000 words or so high-frequency words to comprehend a language.

Nonetheless, determining the specific vocabulary that should be incorporated into the instruction to be taught might pose challenges. Therefore, conducting a corpus-driven examination of the lexicon right from the outset could prove beneficial. The process is called corpus linguistics analysis, and it is defined by Nordquist (2019) [5] as the study of language utilizing extensive collections of "authentic" language usage preserved in computerized databases created for linguistic research. In fact, the act of collecting data and carrying out a corpus-based analysis has been proved to be useful in determining the number of words and classifying them (Chujo & Oghigian 2009) [6]. Through this analysis, educators can identify frequently encountered and pertinent words that might present initial comprehension difficulties, allowing them to better address the vocabulary requirements of their students.

Lextutor.ca is a program that outstands within the range of online programs to learn vocabulary. It was created by Bafia Lufer, Paul Nation, and Thomas Cobb and offers a collection of English and French corpora with different activities that allow learners to expand their vocabulary skills independently or with the teacher's guidance (Villamarin 2021). [7] Even though it is undeniable that the interface is old-fashioned, its multiple benefits to research learn, and teach offset this downside.

2 Theoretical Framework

2.1 Vocabulary Learning

Several researchers in the vocabulary learning field stated the importance of vocabulary acquisition in language learning as a critical part of it (Beglar & Hunt 2005). [8] Alghamdi and Elyas (2020) [9] stated that learners can access a collection of written and spoken input if they have vocabulary knowledge. Thus, vocabulary acquisition should be considered as one of the key parts of language learning. Even though the most effective way of learning vocabulary has been a matter of debate, a significant number of researchers have managed to prove different techniques and strategies that can be applied to different contexts of students in ESL (Alghamdi & Elyas 2020).

A literature review was made with the aim of condensing the current information available regarding vocabulary learning. According to Nation (2017) [10] vocabulary instruction should be done through the high-frequency words of the language and must meet a precise goal for its instruction. Hence, the need arises to resort to the use of databases containing a corpus in which high-frequency English words can be identified.

On the other hand, Balance & Cobb (2019) [11] categorized the materials to learn and teach single words according to the types of vocabulary to learn (Fig. 1):

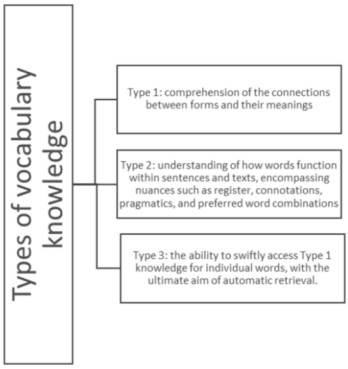

Fig. 1. Types of Vocabulary Knowledge.

This framework enables us to be exceptionally precise in determining whether a specific resource focuses on teaching or reinforcing spoken word recognition, written word recognition, or their interrelation with meaning. It also grants us the flexibility to temporarily set aside resources that pertain to interpreting and producing words in various combinations.

2.2 Lextutor.ca Program

First, it is important to define important concepts such as corpus which refers to an extensive organized body of text that contains distinguishable subdivisions, serving as a representation of language that extends beyond its own content. This representation can encompass an entire language, or the specific language used by a defined group of individuals. By utilizing a modest corpus comprised of classroom materials and incorporating insights derived from research on L2 acquisition, it becomes feasible to anticipate the suitability of these materials for the targeted learners. Additionally, it enables us to identify potential improvements that can be made to enhance their effectiveness, anticipate the challenges and outcomes of the learning process, determine the need for supplementary materials, and ascertain any examinable content resulting from the learners' exposure to the materials (Cobb T 2021) [12].

The Lextutor program has been created with the specific aim of language learning under a large corpus data and it has been a useful tool in studies related to corpus-based analysis showing positive and reliable results (Berg & Kit 2019) [13]. Analysis of the corpora has shown a powerful tool to establish which vocabulary is relevant to be learned. Several studies have concluded three types of lexical lists that the learner should acquire to gain holistic comprehension of the language and the Lextutor program works with; they are K1 refers to basic words; K2 is related to academic words, and K3 is list of terminologies such as linguistics, phoneme and lexical (Abduh & Rosmaladewi 2017) [14].

Under this context, Lextutor is devoted to offering a variety of exercises to work with vocabulary, and some of them are selected to be included inside the EFL classroom. The first is RA-READ (Resource-Assisted Reading) To read books and listen to them

at the same time. Furthermore, Corpus Correct is another tool to recognize grammar mistakes and practice language structure. Moreover, there is the Key Extractor to detect the most recurrent and relevant vocabulary. Then The FlashCards builder is used to create flashcards with definitions and pronunciation. Finally, The Dictator creates writing activities from speech with acceptable pronunciation.

RA-READ (Resource-Assisted Reading). In this section, the learner can read and listen to a book at the same time. There are ungraded (real English) books such as Call of the Wind (in English) and Boule de Suif (in French) and 11 graded (for levels) books in English (Table 1).

Table 1. Graded books available in RA-READ.

Graded Resource-Assisted Talking Books		
	Book	N. Words
1	Island for Sale	1,650
2	Dorian Gray	10,700
3	One-Way ticket (3 stories)	5,450
4	Witches of Pendle	6,045
5	Jungle Book	6,610
6	King Arthur	10,600
7	Oliver Twist	17,300
8	The Lottery Winner	5,550
9	Mutiny on the Bounty	31,090
10	Lost Odyssey 1000 Yrs of Dreams	6,800
11	Gladiator	21,230

Hypertext Builder. It is a tool that allows learners to upload any text and then click on any word to retrieve concordances (sentences containing the word sourced from other materials) as well as definitions. It provides a variety of examples of the word used in different contexts (Fig. 2).

Keyword Extractor. The program discerns the most frequently occurring words within the text and then cross-references this list with the bnc_coca_fams_speechwrite_US _UK_per10mill corpus. This corpus comprises a blend of 10 million terms from both written and spoken US-UK languages and was curated by Paul Nation. Consequently, when a word is found in this corpus list and is reiterated multiple times in the text, the program deduces that it holds significance within our text (Fig. 3).

Flashcard Creator. It permits us to create flashcards with the term and its meaning. The users can select the number of cards (3-100), save the file given a name, and In Card Face A write the word and in Card Face B the definition. The learners have access to the flashcards through a link. Apart from the meaning, the users can listen to the pronunciation of each word (Fig. 4).

Fig. 2. Hypertext builder.

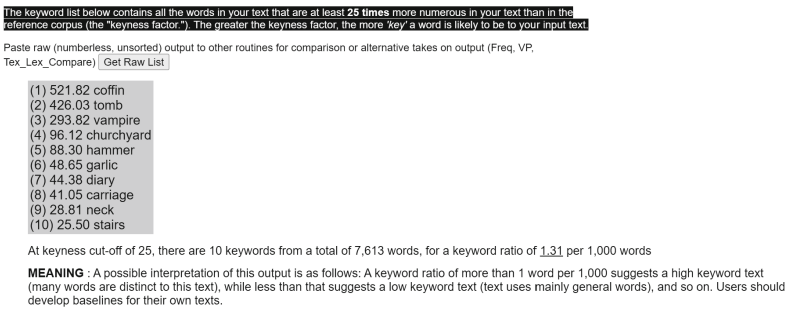

Fig. 3. Example of Key Extractor with a text of "Dracula.

Fig. 4. Example of flashcards created with Flashcard Builder.

Familizer/Lemmatizer. This tool permits to paste or upload the text, and then the program generates a comprehensive list of related words for each term in the corpus, either as a family word list or a complete list of lemmas (headwords, including their inflected and reduced forms, like "n't"). The learner only needs to choose between the "families" or "lemmas" options (Fig. 5).

Cloze Builder. The second type creates gaps according to frequency levels such as academic words, Brown concordances, etc. Upload the text and click on the type of

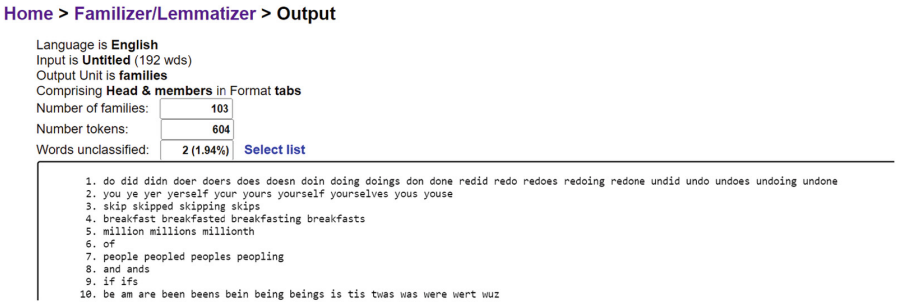

Fig. 5. Example of Familizer/ Lemmatizer.

cloze you want. Then select the number of gaps and options. Add other resources such as dictionaries, audio, or video files, etc (Fig. 6).

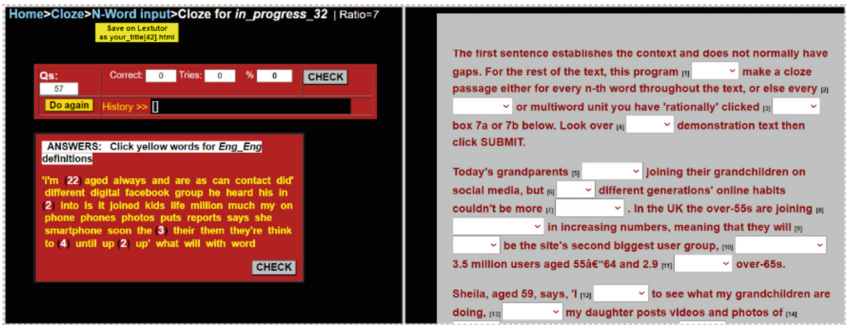

Fig. 6. Example of Cloze builder.

3 Methodology

The methodology used in this research is based on qualitative methods through a bibliographic analysis applying a series of stages that are commonly employed in bibliometric studies and literature reviews. These stages included: determining the research objectives; establishing the criteria for document inclusion and designing the research program; and conducting an analysis if the chosen documents. The introduction section defined the study objective.

The method section was based on document selection criteria; while the analysis and results, addressed the documents' analysis. At this stage of the process, an attempt was made to structure the information in a coherent and accessible way, with the purpose of deriving the conclusions that emanate from these data. For this study, some previous papers by authors who made contributions on the methodology were contrasted, to guarantee the content quality of the information presented. English was chosen as the language for the documents, given its predominant usage in academic and scientific publications.

4 Survey Results

With the aim of obtaining data regarding vocabulary instruction and learning, a small population of English teachers went on a survey. Due to its ease, a short Google Forms questionnaire was designed and touches on topics related to the vocabulary teaching-learning process and corpus-based software use. The topics included in the survey, along with their results, are displayed below.

Techniques and Strategies for Vocabulary Instruction. The first section addressed the need to find out the techniques used in the vocabulary teaching process. Results are shown as follows; vocabulary exercises received 46.9% of acceptance, while gamification 43.8%. The responses that received the lowest percentage were translation of terms at 6.3%, and audio-based teaching at 3.1% (Fig. 7).

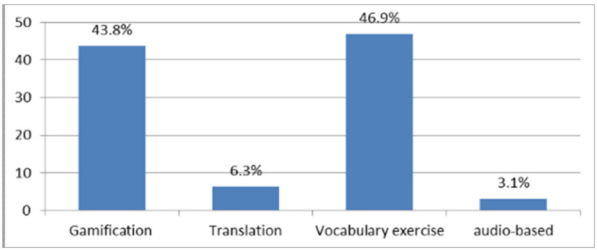

Fig. 7. Techniques and strategies for vocabulary instruction.

Vocabulary Selection. The second topic focused on how instructors select the target vocabulary to teach, in this section, surveyed teachers were given the option to choose more than one answer since not all cases rely on a single approach. The majority, accounting for 34%, answered that they primarily base their selection on the book content. Not far behind, 26% of teachers indicated that they rely on the levels proposed by the Common European Framework (CEFR). In third place, with 20% it was found that they rely on readings or texts, followed by 15% basing their selection on songs and the last 5% pertains to narratives (Fig. 8).

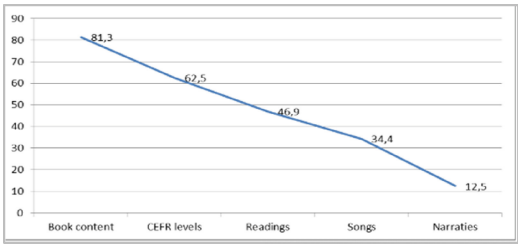

Fig. 8. Vocabulary selection.

Use of a Corpus-Based Program. To avoid confusion with the term "corpus" a definition by Al-Gamal & Ali (2019) was provided in the third discussion topic "A corpus is a large collection of written or spoken texts that can be developed manually or electronically and be representative of the authentic language data" Thus, 78.1% admitted to not having incorporated a corpus-based program, while the remaining 21.9% have used it.

Software in English Teaching. In this discussion topic, surveyed teachers were given a two-part question, one with a closed-ended answer regarding the use of software in the English language teaching process. 62.5% replied affirmatively, while the remaining 37.5% admitted not using any. This is followed by an open-ended question designed to find out the names of the software used. The results are shown below, with Kahoot and Richmond Platform being the most mentioned ones (Fig. 9).

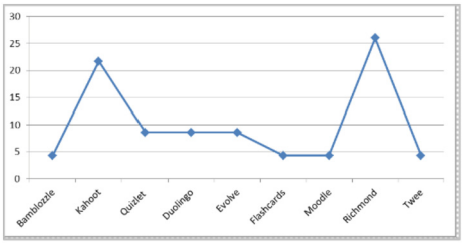

Fig. 9. Software for English teaching.

Willingness to Use Software for Vocabulary Practice. The last question aimed to determine if teachers would be willing to use software to practice vocabulary through contextual activities. The results show a 100% acceptance rate regarding the use of it.

5 Conclusions

After an analysis, it is undeniable that the exercises included in course books are certainly beneficial; however, for weak learners simply encountering words in a logical order might not be enough to achieve independent reading skills or expand their vocabulary further. These learners require additional opportunities, such as a vocabulary supplement, which reintroduces newly encountered words from the text in a different, more memorable format, or within a more easily understandable context (Cobb T. 2021).

Some valuable resources are freely available in the Lextutor.ca program such as the ones mentioned in this study. When learners use technology can encounter low or no-cost data easily and from different sources than using printed texts. According to Cobb (2018), resource-assisted reading (with most of the resources obtained from Lextutor.ca) provokes that the acquisition of searched vocabulary typically sees a boost ranging from 70% to 80% in contrast to non-assisted reading.

Even though some important vocabulary material might be obtained from the book content, the use of corpus analysis as a resource will provide further vocabulary that

appears recurrently in a text and has significant relevance in the language (Cobb 2018) [15]. A good tool for this objective is the Key Extractor program because it compares the text entered with a list of 10 million words of corpora and identifies the most recurrent words as predominant in the text. Once students attain a strong grasp of vocabulary, they acquire the ability to spontaneously define meanings and contextualize situations as they read. (Mousavian & Siahpoosh 2018)[16].

Through the survey, it was revealed the lack of knowledge about the use of corpora to teach ESL vocabulary. Corpora has been a valuable tool in linguistics research since the 80s. Nowadays, corpus analysis plays an increasingly significant role in the process of learning a second or foreign language. These corpora can be utilized to create educational materials that cover all language skills, including reading, writing, listening, speaking, and vocabulary, as pointed out by Al-Gamal and Ali in 2019.

Moreover, corpus linguistics methodology enhances learners' linguistic proficiency in areas such as synonyms, antonyms, homonyms, and polysemy (Cobb 2018) due to it decodes from the most elementary components of the text, such as individual letters, morphemes, and graphemes, and progresses towards comprehending sentences and entire texts as an effort to grasp the language. (Villamarin 2021).

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Study on Stereo AI Based Zed-2i Camera

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Abstract. This article examines the possibility of successfully integrating the ZED-2i stereo camera with AI-enhanced technology. A sample of two different environments with different characteristics is assessed to determine the viability of implementing this in a real-world setting. The results show a significant difference in cloud detection between indoor and outdoor environments, with higher detail levels in point clouds. Essential factors include depth recognition, cloud clustering, and light conditions. Quality parameter settings were found to mitigate the adverse effects of localization and visual odometry inaccuracies. The findings from analyzing experiments display the importance of hardware and software configurations. Future research is required on the newer version of the camera with Jetson NX Orin implementation to explore and develop the utilization in specific sectors like agriculture and forestry.

Keywords: Stereo camera · ZED camera · ZED-2i camera · Visual Odometry · RTAB-Map · ROS · Stereo AI · Jetson NX Orin Module

1 Introduction

In robotics, the integration of visual inputs and the ability to use them to map environments is essential. In autonomous robots, stereo cameras enhanced by AI technology have the potential to create new ways of detecting such as objects and obstacles. The depth perception from a stereo camera and the analytical power of AI algorithms give robots the ability to represent a better image of the environment and interact to make more precise avoidance maneuvers because of the higher precision in mapping and localization. This article aims to get more knowledge on the workings of a ZED stereo camera series and determine its purpose in real-world applications. The use case of the ZED-2i stereo camera in this article is intended to be utilized in indoor and outdoor (forest) conditions, where there are several obstacles and smaller objects to map.

Kesse Jonatas de Jesus et al. show in [6] that RTAB-Map, in combination with stereo cameras in an outdoor environment, accurately measures the location traveled by a robot. In [4], it is also mentioned that RTAB-Map appears to be a fast approach to creating 3D maps, which could be helpful in certain situations.

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The experiment showed a slight offset of the original path while turning on the horizontal axis. This article focuses on singular axis movements of the camera that simulate the use case of a four-wheeled robot. In [1], Nihal Altuntaş et al. state that RTAB-Map is superior in translational movements but has a higher error rate for rotational movements. Characteristics of RTAB-Map regarding the localization are sufficient as demonstrated in [3,5] with different hardware limited configurations. Guifu Zhang et al. results display in [8] that the accuracy might vary depending on the camera used for visual mapping in indoor environments. RTAB-Map

In [9], Ahmad Firdaus et al. shows the positional recognition and path tracking of the ZED 2 stereo camera with the robot's corresponding error rate and response time. The older version of the ZED camera has also been analyzed on depth error registration at multiple depth levels in [2]. These results are valuable for analyzing this article's results based on the instabilities of the experimental setup. Other features in the stereo camera are the depth sensing qualities demonstrated on an electric socket in [11] by Vladimir Tadic. Modification in the algorithms seems necessary regarding the depth detection to collect the cloud density aimed for through point cloud.

The following section will discuss other literature and articles to better understand what to expect and what details to consider during the experiment. Then, in Sect. 2, related materials such as hardware and software will be discussed. In Subsects. 3.1 and 3.2, the experimental setup and results are briefly discussed. In Subsect. 3.3, the results are sorted into categories to structure the results more thoroughly. Furthermore, in Subsect. 3.4, the results will be closely analyzed. In the last Sect. 4, conclusions about the findings will be summed up.

2 Installation Method of ZED-2i Camera

In this section, we will be discussing the hardware interface of the ZED-2i camera, the software and tools used, the CUDA toolkit, and other possible extensions and features.

2.1 Hardware Interface of ZED-2i Camera with Computer

The following section will introduce the materials, such as hardware and software used for the experiments, to understand better how the results have been achieved. Table 1 sums up the electronic parts in two sections, starting with the computing system and continuing with the camera equipment used.

2.2 Software and Tools Used

Operating System
The choices of operating systems are limited due to the compatibility requirements of other essential software. Linux-based operating systems are compatible

Table 1. Hardware specifications of experiment setup

Parameters	Configuration
Computing system	
Computer model	Dell XPS-15-9510
Processor	11th Gen Intel(R) Core(TM) i7-11800H @ 2.30GHz
GPU	NVIDIA GeForce RTX 3050 TI
RAM	32 GB DDR4
Camera equipment	
Camera	Stereolabs ZED-2i
Connector cable	USB-C 3.0 1.5 m locking cable
Adapter	DELL USB-C to USB-A adapter

and versatile with robotics software. This research utilizes ROS1, Robotics Operating System 1, compatible with Ubuntu versions 20.4 and 24.4. These Ubuntu versions are LTS, Long Term Services, and provide support and essential updates for longer. Obtain the ISO file of the correct Ubuntu version directly from the official source. Utilize an open-source tool for creating a bootable and put this on a removable memory drive. The installation steps should be followed closely, but make sure to allocate sufficient cores and memory to ensure this won't be a limiting factor during the experiments. Furthermore, using the Ubuntu Pro option is recommended, offering additional benefits such as security updates that last multiple years.

NVIDIA Graphics Driver

Selecting the suitable configuration of NVIDIA drivers is essential to smooth operations. Without the correct driver, the operating system won't recognize the GPU. The available drivers can be accessed via "Software and Updates" under the additional drivers tab. The driver's newest version at installation can be selected, but avoid choosing the open kernel version. Be aware that the NVIDIA driver updates might lead to issues if not addressed in advance. Blacklist the Nouveau driver by creating a configuration file with the parameter "nouveau modeset=0" as shown in Fig. 1. The next step is to confirm the current version of the driver and if the GPU is detected by using the following command in the terminal "nvidia-smi". If the message "GPU or drivers not detected" appears, we need to see the additional drivers tab and downgrade if necessary. In this article, the driver version 525.125.06 has been used as this is a stable release at the point of testing. In case of sleep mode activation or driver detection problems, restarting the system often solves driver-related problems. If this does not solve the issue, we also took assistance from the community forum to find the proper solution.

Robot Operating System Framework Installation

ROS, which stands for Robot Operating System, is a versatile toolset for developers to interact with robots. ROS is available in different versions and distribu-

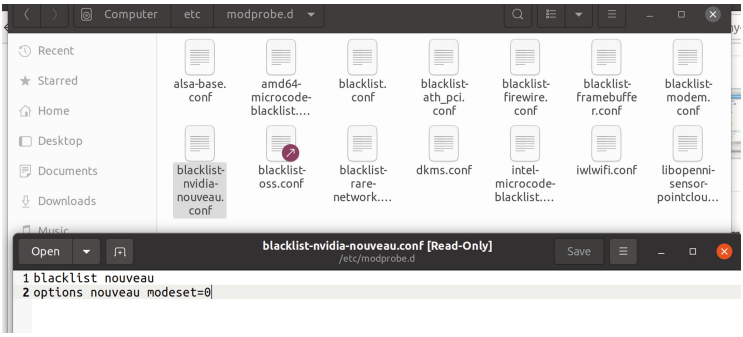


Fig. 1. Nouveau driver blacklisting

tions specific to the operation system. According to the previously mentioned OS version running on the system, the suitable ROS distribution would be Noetic. Noetic is compatible with Ubuntu 20.4 and Python 3 and is the latest supported release. Opting for the complete Noetic installation guarantees that the most essential packages are included for 2D and 3D simulations. This paper focuses on 3D simulations, making the entire structure the preferred option to eliminate the need to download fundamental packages individually. Official pages provide installation guides to simplify the installation and setup procedure. After installation of the environment, it needs to be sourced, which is recommended to be automated to manage dependencies. Establish a new workspace, serving as a place to install other packages from external sources.

ZED SDK

Stereolabs, the manufacturer of the stereo camera, provides a comprehensive software package designed to enable the camera's complete potential. This service development kit has integrated features and algorithms, which are ready to run and include preset configuration files. This research focuses on utilizing specific features and functionalities to determine their potential in future applications. These two main elements are positional tracking and spatial mapping, also called SLAM. SLAM, which stands for Simultaneous Localization and Mapping, is a renowned way for robots to navigate and understand their surroundings.

ROS Packages and Nodes

As mentioned in the ROS installation section, depending on the implementation, the system needs external packages, also known as system dependencies. In the case of the ZED-2i, a specific package is available that includes the nodes that enable the functionalities of the ZED SDK. This package is referred to as "ZED-wrapper," and it allows the camera to provide the following information output through the ZED node: camera left and right imaging, depth map, point clouds, and pose information. These output topics are required as inputs for 3D mapping and localization processing. The SLAM approach utilized is the RTAB-Map, a Real-Time Appearance-Based Mapping package. RTAB-Map uses an enhanced

loop closure detection method and algorithms to determine new frame images to the corresponding location.

2.3 CUDA Toolkit

CUDA, which stands for Compute Unified Device Architecture, toolkit from NVIDIA plays a vital role in facilitating the total computing power of a GPU. The Stereolabs SDK requires the libraries and architecture that CUDA enables. Integrating parallel GPU processing supplies the deep learning algorithms with the computational power needed. Selecting the corresponding CUDA version according to the other software versions mentioned earlier is crucial. Currently, ZED SDK 4.0 supports CUDA version 12.0 and is also compatible with Ubuntu 20.4. Older versions of CUDA that are working on the Ubuntu-18 platform are deprecated, which makes it not recommended to use. The CUDA deep learning models are ideal for the ZED-2i stereo camera, which operates, for example, imaging, color correction, and visualization floating-point computing. Issues regarding the NVIDIA driver also apply to the CUDA installations, with instances in the operating system that do not detect the software. Verifying the detection of CUDA can be done utilizing the terminal in the same way as described with the other drivers.

2.4 Other Extensions and Features

In configurations regarding software-related matters, other things still need to be considered. One of these is to manage and execute the 3D map data to be retrieved and analyzed after the experiment. There are several ways of doing this within ROS, such as using the RTAB-Map data recorder. An effective approach involves recording map data during experimental sessions with different parameter files, giving insight into the camera's attributes and limits. The recorded database contains crucial information and can be examined through applications like Meshlab or the RTAB-Map standalone database viewer. Setting up nodes and managing the information and topics being subscribed and published can sometimes be challenging. In response, ROS provides an RQT graph tool that visualizes nodes and topics within the application and how these interact with each other. This tool significantly enhances the understanding of the system and solves communication issues during the tweaking and testing phase.

3 Experiment Execution and Results in Different Environments

The experiment setup with the outlined configuration earlier has been deployed for several tests in different environments. The configuration files have been adjusted to optimize performance according to the surface structure of the area in this specific environment. Fine-tuning of the files has led to notable improvements in outcomes. These improvements will be assessed with positives and negatives observed during the execution of the test runs.

3.1 Indoor Experiment

Execution of the indoor experiments involves office spaces, corridors, and an electric laboratory, all by walking through the area or stationary 360-degree camera rotation. Note that the initial round of indoor tests had a less advanced node, package, and parameter setup script.

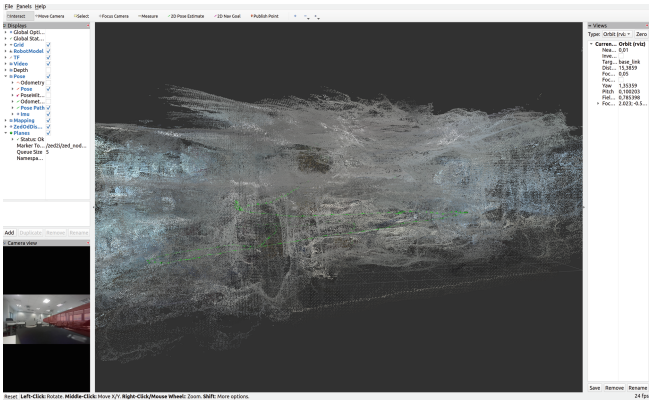


Fig. 2. First indoor experiment in lecture hall

The first experiment, as captured in Fig. 2, shows the initiated primary results with many challenges concerning cloud density and surface detection. However, larger structures like pillars, doors, and windows remained easier to recognize. Individual point clouds did not display the correct color coding and showed little or no clustering. After the first experimental experience, a modified version of nodes and parameters is prepared to be deployed. The modifications to the configuration are aimed at eliminating the limitations of the first experiment.

Figure 3 presents a more advanced cloud clustering and color grading level. The camera captures objects with more detail, such as square light pods in the ceiling, wooden doors, and walls. These objects have a higher cloud cluster density than the earlier example. The outcomes are outstanding around brighter areas, for instance, emergency exit signs and within the back room, where sunlight comes through the windows. Besides that, it faces challenges detecting several larger objects like workbenches.

Continuing the indoor test run, the camera is rotated and moved minimally along the x and y-axis, making it almost stationary. This approach accentuates the difference and ability of the camera to effectively identify smaller objects and differentiate colors in the environment, as illustrated in Fig. 4. Even surfaces like cabinets and a flat green wall, computer monitors, boxes, desks, and chairs can be identified. Certain clouds are incorrectly picked up or duplicated in positions like the monitor and a brown bar extending from the door.

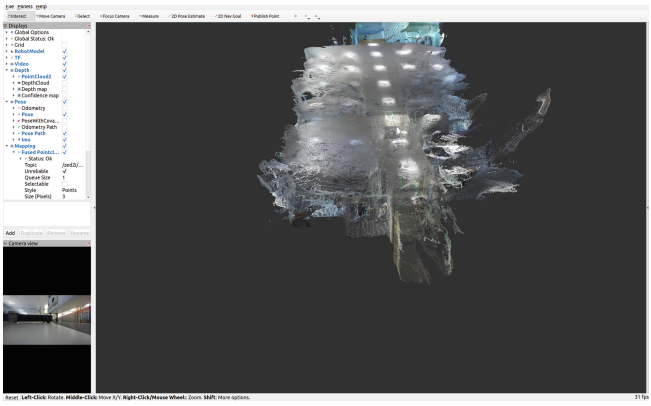
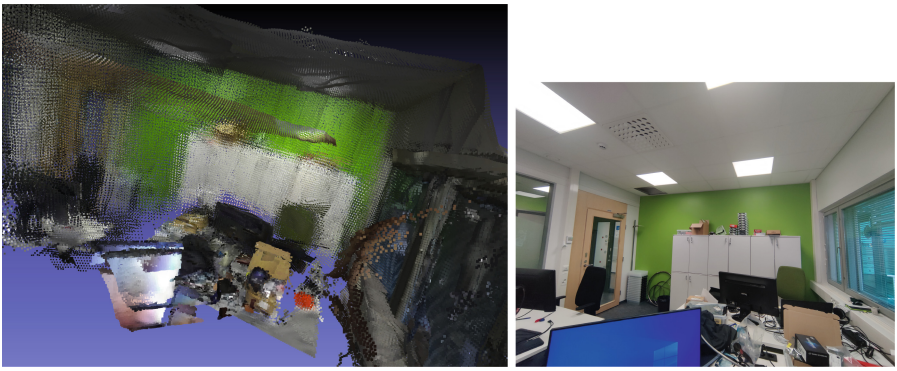


Fig. 3. Second indoor experiment taken in the electric laboratory



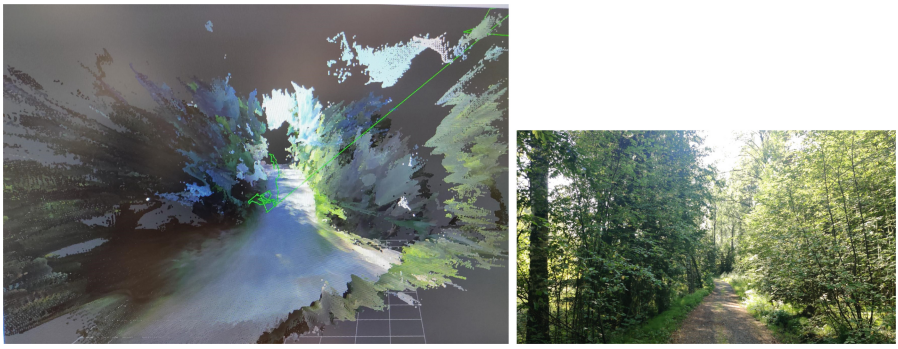
(a) Point cloud (b) RGB

Fig. 4. Final indoor experiment in the office

3.2 Outdoor Experiment

Outdoor experiments are conducted by walking and traversing a dirt road with plenty of bushes and trees on either side. The capturing process is initiated by the launch file at the start of the road until a particular turning point before returning to the initial position. The camera is manually carried and positioned approximately 1.5 m above the ground. Figure 5 illustrates the upper perspective of the resulting outcome.

From an elevated viewpoint, the shade pattern from trees becomes distinctly noticeable on the road. The shade is of precise shape that matches the branch that obstructed sunlight on the ground. It is worth mentioning that there is noise in detecting the sky because of the bright sunlight reflection in the camera. This occurrence is observed mainly in the upper middle and upper right section of Fig. 5. The issue could potentially be linked to either camera polarization or the



(a) Point cloud (b) RGB

Fig. 5. Top view of first forest experiment

angle of sunlight. Throughout the recording process, the shaping of objects via point cloud mirrors real-world observations surprisingly well.

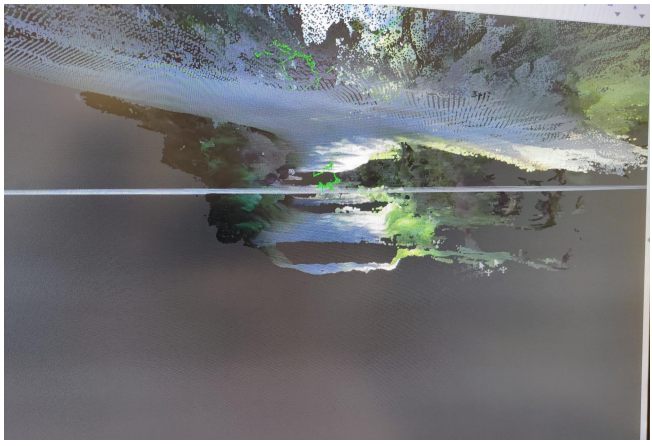


Fig. 6. Horizontal view from the x-axis during first forest experiment

Upon reviewing the results, an issue becomes visible regarding the layering of the environment based on the camera's visual odometry-based localization method. The background was captured as intended up to the turning point, as visualized in the lower section of Fig. 6. At the point of turning, a shift on the y-axis was recorded, leading to an additional layer being built on top of the original. The quality of the first half of the experiment, the lower section, contains a higher clarity and increased cloud density. In conflict, the upper section has a lower density, and clouds are scattered around and do not form recognizable objects or structures.

3.3 Pros and Cons of Results

The positive and negative impacts are displayed in Table 2 acquired from the experiments. These items are based on the influence on the outcome and are categorized as a positive and negative impact, showing whether it is favorable or unfavorable. The impact is rated based on the implementation case described in the introduction. The exact implications range from low to high, showing the strength of the impact, making a solid result more noticeable than low impact.

Table 2. Benefits and drawbacks of experiments

Item	Impact on use case
Positives	
Captured shadows	High
Amount of clouds	High
Light conditions	Low
Negatives	
Flat surface detection	Low
White balancing	Low
Color representation	High

3.4 Implication and Impacts of Results and Future Direction

Analyzing the trial outcomes reveals a considerable difference in 3D maps from indoor and outdoor environments. Within the test, a visual odometry problem appeared sporadically, which went unnoticed, as this issue can be seen in both experiments. After examining the results, a solution was found by modifying the quality parameter from “Ultra” to “Neural.” This feature integrates built-in AI algorithms that enhance the precision of odometry to improve localization registration. Follow-up trials demonstrate improved results by merging the layers and having sharper and more complex object imaging.

During the indoor experiments, the ZED-2i in this configuration was shown to be sensitive to movements, confirmed by its inaccurate lack of cloud detection. For instance, a duplicated monitor screen and a brown bar of clouds were depicted extending from the door. It is worth noting that these inconsistencies don’t replicate the real-world scenario, and such inaccuracies could mislead a robot into making false decisions. This concern could be solved by incorporating different or additional algorithms like Octomap. It has to be an approach that involves reevaluating and updating specific point clouds to effectively reduce the impact of movements within areas with elevated activity.

Recreating the identical experimental with the more recent version of the ZED camera series can yield valuable insights into the capabilities of AI algorithms and the stereo camera. The ZED X is the most recent stereo camera

version offered by Stereolabs, where the ZED X camera is integrated with the ZED box, which is the Jeston NX Orin with preinstalled software and algorithms. In future studies, there should be intensive testing of this setup to use all the computing power of these devices and to achieve optimal outcomes.

Furthermore, the stereo camera should also be subject to testing across diverse outdoor environments. Such analysis gives a deeper understanding of the cameras' feasibility and utilization conditions. Collecting the output data can be used to guide a physical robot for better judgment on the provided inputs. Experimenting with a stereo camera has been demonstrated to be somewhat accurate working by Germán Ramírez, Andrés Montes de Oca, and Gerardo Flores in [10]. Similarly, another application with limitations to consider for future research implementation has been demonstrated by Levente Göncz and András Majdik in [7].

4 Discussion and Conclusion

The results presented in Subsects. 3.3 and 3.4 highlight the potential of ZED-2i for immediate and future integration into advanced robotics. Nevertheless, it is essential to acknowledge that the camera's performance might exhibit variances influenced by lighting conditions, object densities, and overall scene complexity. The camera captures enough information and maintains consistency to make this setup reliable. ZED-2i stereo camera performs exceptionally well in environments with more minor, non-flat objects in scenarios like forests. It can capture fine details like branches within these dense landscapes, which is remarkably impressive. In contrast, the suitability in current testing with the configurations is particularly not good in dynamic areas where movements could cause inaccuracies in 3D mapping. Defining ZED-2i's strengths and limitations establishes a foundation for assessing potential applications within specific sectors.

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Systematic Review of Motion Sensors and Their Energy Efficiency

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Abstract. In today's technological landscape, there have been significant advancements in automating devices to minimize direct physical contact with objects. Instead, these devices rely on various sensors to recognize objects through methods such as waves, signals, or temperature. Among the plethora of sensors available, it is crucial to identify the optimal ones that consume less energy. This research aims to explore motion sensors that are both optimal and energy-efficient while also determining the availability of resources associated with home automation. To achieve this objective, a systematic review was conducted, which involved collecting data to address the following research questions Q1: How many studies have been conducted on motion sensors, Q2: Which sensors consume less energy and contribute to energy efficiency. By analyzing the results obtained from the research, it is possible to determine the optimal motion sensor and identify the sensor with the lowest power consumption.

Keywords: Motion sensor · energy efficiency · automation

1 Introduction

The technological evolution and the high demand for devices that facilitate people's lives, are the sensors, these are considered as devices that react to a certain input or stimulus, thereby generating a response, which is usually an electrical signal, according to [1]. Currently, the development of these devices has increased in relation to energy efficiency and quality in industrial processes and homes and has also encouraged research and scientific development towards new components oriented to artificial intelligence, as mentioned by [2].

According to [3, 4] sensors allow responding to a huge set of applications and functionalities such as turning on the light once the natural light fades at dusk or once in a dark place a displacement is initiated which, when picked up by the sensor, turns on

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the light. Motion sensors detect human presence both day and night, whether moving or not, by converting an IR from the human body into an electrical signal, as stated by [5]. The variance in motion patterns plays a fundamental role in motion analysis, therefore, it should be considered, as reported by [6]. Thus, they also allow a larger volume of data to be collected and activity data to be better used as behavioral measures [7].

This study aims to conduct a systematic review of the types of motion sensors and their energy efficiency, to observe two fundamental aspects, first, to identify which motion sensors are technologically optimal. Second, to distinguish the sensors that consume less energy, the latter to analyze the sensors that contribute better to efficiency and energy management.

2 Methodology

This research is based on the literature review about motion sensors and their energy efficiency, the search was focused on scientific documents such as journals, books, and articles. The criteria [8] were considered for the development of this study in three stages: research planning, development of the information search and results found. These criteria are the formulation of research questions as a support that accompanies the entire research process, they are the basic guide of the review since they allow discerning and making decisions about it.

2.1 Research Planning

The following research questions were elaborated as a guide to reach the research objective: Q1: How many studies refer to motion sensors, Q2: Which sensors consume less energy and contribute to energy efficiency? For the information search criteria, the identification of terms associated with the topic as keywords was considered, as indicated by [9]. IEEE Xplore, Science Direct, Springer and ACM Digital Library, are the information sources where the information search was performed using logical operators and keywords, among which are: motion sensors, application of motion sensors, types of motion sensors, motion sensor parameters, motion sensor factors, motion sensor applications and keywords to be used to elaborate the information search chain.

The inclusion criteria were used to select information found in articles, book chapters, and books that are related to the research questions. This search focused on studies that had been published between the years of 2017 to 2023.

2.2 Procedure for Information Search

In this stage, Fig. 1 shows the information search process, considering the criteria detailed above.

The search process was performed by applying the search string to each of the data sources related to the literature on motion sensors and their energy efficiency, so a review and purging of articles that did not meet the established criteria or that were duplicated in different sources of information was performed. After that, the summary of the articles found was reviewed and a total of 28310 research papers were eliminated, obtaining 289

potential studies from this process, from which the complete content of each of these articles was reviewed and, because of the analysis of these, a total of 76 articles were obtained, as shown in Table 1.

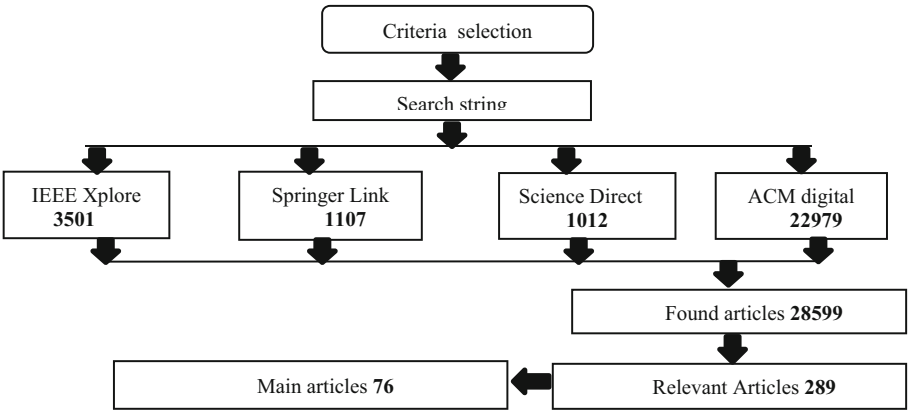

Fig. 1. Search process

Table 1. Search results.

Source	Total studies found	Promising studies	Main studies	%
IEEE Xplore	3501	38	11	14,47%
Springer Link	1107	41	19	25,00%
Science Direct	1012	27	10	13,16%
ACM Digital Library	22979	183	36	47,37%
TOTAL	28599	289	76	100,00%

2.3 Obtained Results.

2.3.1 Results Found Concerning Q1 How Many Studies Refer to Motion Sensors?

Based on the results found in relation to Q1: How many studies refer to motion sensors? A total of 45 main studies detailing the various motion devices were obtained. See Table 2.

A review and purging of articles that did not meet the established criteria and that were duplicated in different sources of information was carried out. As a result, a total of 393 potential studies were obtained, and their respective summaries were read, obtaining 45 main studies. When reviewing the main studies, data of interest were obtained, which serve to understand their parameters of use, technical, among others. Table 3 lists the sensors found, manufacturers, and in which fields they are applied.

Table 2. Search string results.

Source	Total studies found	Promising studies	Main studies	%
IEEE Xplore	42621	129	11	24,44%
Springer Link	11045	42	5	11,11%
Science Direct	7141	25	2	4,44%
ACM Digital Library	68046	197	27	60,00%
TOTAL	128853	393	45	100,00%

Focusing on motion sensors, which are the subject of interest in the research, several devices were found, from which several relevant specifications were obtained, comparing their effectiveness according to each parameter. See Table 4.

Table 5 shows sensors that are commonly used. These are detailed in the way in which they work and the sites in which they can be applied.

2.3.2 Results Found Concerning Q2: Which Sensors Consume Less Energy and Contribute to Energy Efficiency?

According to the articles reviewed, several sensors were found, which in addition to being classified by their parameters, are also implemented with algorithms, which allow the equipment to be optimized, and in the same way, improve its operation, extending its useful life, and collaborating in improving the energy efficiency of the site where it is used, the results found are detailed in Table 6.

There are several parameters that are considered when acquiring a motion sensor. In this case, [49] was considered to obtain several important data from two motion sensors offered for use. The parameters such as temperature, detection distance, installation height, power consumption and voltage, are detailed in Tables 7 and 8 where it can be seen which of the PIR and microwave type sensors, is the one that consumes less energy and contributes to energy efficiency.

Table 9 describes the trends in energy efficiency, the development of energy-efficient sensors and how they are contributing to energy efficiency in various fields, such as industry, transportation, smart buildings, agriculture, etc.

Figure 2 shows the bar chart that provides a visual representation of the percentages of energy efficiency in relation to the various sectors of industry, transportation, buildings, agriculture, renewable energy, and IT efficiency.

Table 10 describes the latest advances in motion sensor technology, based on thermal imaging, radar, and LiDAR technology.

Table 11 describes the technical characteristics of different voltage sensors with functionalities that can contribute to the collection of home consumption voltage data with the necessary accuracy.

IoT enables the interconnection of devices and sensors to collect data and make intelligent decisions in real time. Table 12 describes how IoT is used to optimize

Table 3. Sensors found and their application.

Sensor	Manufacturers	Applications	Ref.
Inercial	ASC, MicroStrain, Epson Europe Electronics, Hon-eywell Sensing and Inter-net of Things, Shenzhen Rion Technology Co.,Ltd, Systron Donner Inertial, Texys	Robotics (measuring speeds, accelerations of each link), human gait analysis, ergonomics studies, animation	[10], [11], [12]
Kinect	Microsoft, Shenzhen Hai-hongchang Electronics Co., Ltd., Apple	Facial and gesture recognition. Tasks in the operating room, information about your body (movements, position of the extremities, voice, etc.)	[13–16],
PIR	Accurate Sensors Technol-ogies Ltd, AOIP, Bookham, Cefem Group, InfraTec GmbH Infra-rotsensorik und Messtech-nik, Magnetek, Monarch Instrument, Pixsys	Domestic, Medical and Life Sciences, Surveillance or Security Cameras, Aviation and Land Security, Automotive, IT Peripherals and Consumer Products	[17–20],
GRID-EYE	Panasonic, Mikro-elektronika	Patient monitoring, motion detection, thermal imaging, position detection	[18, 21, 22]
MEMS	Omron Corp, Nikken Sekkei	Reduce energy consumption of lighting or heating equipment because they can be equipped with greater automation resources to regulate themselves, such as house lights	[23–26]
Infrared human detection AK9750	AKM, Mustwell, ASIN, BliliDIY, Man-hj	Computers, Tablets, IoT applications, home appliances, Lighting systems, Home appliances, Smart locks, Door phones, etc	[7, 15, 27, 28]

(*continued*)

Table 3. (*continued*)

Sensor	Manufacturers	Applications	Ref.
Ultrasonic	ERCO, Magza, MELCSA, CALFER, ISEL	In Food and Beverage Industry, Packaging and Assembly, Proximity Measurement	[18, 29, 30]
Movement	Autonics, Dominion Indus-trial, Boxio, EYCA Total Security, SECRA, GIRA, ZUMBTOBEL, Bticino, TURCK	Domestic, Aviation and Homeland Security, Automotive, IT Peripherals and Consumer Products, Common Area Lighting	[5, 7, 31, 32]

Table 4. Motion and detection sensors

Motion sensor and/or detector	Light sensitivity	Height	Angle of detection	Diameter	Voltage	Ref.
Recessed Motion Sensor360º, Detection 6 m Ip20	<3–2000 lx	2.2–4 m	360º	75,50 mm	230 V-AC	[33, 34]
Steerable Motion Detector 180º Pir Ip44	3–2000 lx (Adjustable)	1–1.8 m	180º	65 mm	220-240 V/AC	[5, 35, 36]
Movement sensor Led Para Pared Pir 160º	<3–2000 lx	1–2 m	160º	59 mm	230 V-AC	[5, 37]
Ceiling Surface Motion Detector, Detection 360º	<3–2000 lx	2.2–4 m	360º	114,50 mm	230 V-AC	[24, 38]

energy efficiency in applications such as smart lighting, power demand management, and monitoring of energy equipment and systems.

Table 5. Sensor Functionality and Application

Motion sensors	Function they fulfill	Application	Ref.
Infrared motion sensors (PIR)	Their input signal is transmitted to the central signal, they measure and compare the infrared radiation in their detection zone	Fences, Offices, Corridors	[39–41]
Twilight sensors	Capable of detecting dusk and dawn, allowing it to connect or disconnect the loads connected to its output accordingly	Luminaires (Outdoor Lamps)	[42]
Presence sensors E27	Capture motion due to infrared emissions from any heat source	Luminaires (spotlights, lamps), Schools, Offices	[43, 44]
Surface presence detectors	Detect any movement in the area where it is installed	Lighting, air-conditioning, ventilation, or surveillance systems	[45]

Table 6. Types of sensors with applied algorithms.

Motion sensors	Algorithms used	PARAMETERS					Ref.
		T°C operation	Brightness range	Voltage	Frequency	Angle Detection	
Infrared motion	Adaptive recalibration algorithm	−15 a 70 °C	10 a 2000 lx	5 a 20 Vdc	50 a 60 Hz	110°	[46]
Twilight type	N/d	−20 a 45 °C	5 a 300 lx	230 Vac	50 Hz	180°	[47]
Presence E27	DV hop localization algorithm	0 a 35 °C	10 a 2000 Lx	110 a 240 V	50 a 60 Hz	240°	[48]
Surface presence detectors EE820	ICP	−25 a 50 °C	5 a 1000 Lx	230 V	50 a 60 Hz	140°	[49]

Table 7. PIR Sensors (Indoor) Recessed Ledvance

Code	85196	85197	7015810	7015811
Dist. Max. detection	6 m	8 m	6 m	8 m
Temperature	24 °C	24 °C	24 °C	24 °C
Working time	<10–2000 Lx	<10–2000 Lx	<10–2000 Lx	<10–2000 Lx
Time to shutdown	7s a 17 min	7s a 17 min	7s a 17 min	7s a 17 min
Installation height	2.2 a 4 m	1.5 a 3.5 m	2.2 a 4 m	1.5 a 3.5 m
Range	360°	360°	360°	360°
Voltage	127 V	127 V	220 V	220 V
Consume	0.7 W	0.5 W	1.2 W	0.9 W

Table 8. Recessed Microwave Sensors

Code	85198	85199	7015812	7015813
Dist. Max. detection	10 m	10 m	10 m	10 m
Working time	<10–2000 Lx	<10–2000 Lx	<10–2000 Lx	<10–2000 Lx
Time to shutdown	7s a 17 min	7s a 17 min	7s a 17 min	7s a 17 min
Installation height	2.2 a 4 m	1.5 a 3.5 m	2.2 a 4 m	1.5 a 3.5 m
Range	360°	360°	360°	360°
Voltage	127 V	127 V	220 V	220 V
Consume	0.3 W	0.4 W	0.4 W	0.5 W

3 Analysis

A total of 28599 studies were obtained as a result of the systematic review carried out in this research, of which ACM Digital Library represents 47.37% of the main studies found, being the library in which the largest number of articles were obtained (36); followed by Springer Link with 19 main studies, corresponding to 25.00%; IEEE Xplore with 11 main articles, representing 14.47%; and finally Science Direct with 13.16%, equivalent to 10 main studies found.

In relation to Q1, How many studies refer to motion sensors, a total of 45 main studies were obtained, among which a diversity of devices that detect the movement of people or objects were found, which vary in their characteristics depending on the application to which they are subjected. Among the sensors found are those of inertial type, Kinect, PIR, GRID-EYE, MEMS, Infrared human detection AK9750, ultrasonic, motion, all these devices and their parameters of use are described in this research.

The studies were considered and based on the parameters of the devices, which have algorithms for location, temperature, movement, among others; these present better efficiency in relation to their use in the site where they are located. Likewise, the PIR

Table 9. Current trends in energy efficiency

Field	Trends	Contribution	%efficiency	Ref.
Industry	Low power sensors and wireless communication	Enable more efficient monitoring and control of industrial processes	20%	[50, 51]
Transportation	Energy management and performance monitoring sensors	Optimization of fuel and energy consumption in vehicles and transportation systems, leading to greater efficiency and reduced emissions	50%	[52]
Buildings	Intelligent lighting and climate control sensors	Automatic control and adjustment of lighting and climate control based on occupancy and environmental conditions, resulting in lower energy consumption	50%	[53, 54]
Agriculture	Soil moisture sensors and irrigation management	Improved irrigation efficiency by providing accurate soil moisture data, preventing overwatering and water waste	30%	[55]
Renewable energies	Sensors for solar tracking and yield monitoring of solar panels	Increased solar power generation efficiency by automatically adjusting solar panels to maximize sunlight collection and performance	20%	[56]
IT Efficiency	Sensors for power consumption and performance management of IT equipment and data centers	Identification of opportunities for energy savings and optimization of IT infrastructure, resulting in increased efficiency and cost reduction	80%	[57]

and Microwave sensors, showed that they are those that consume less energy (w/h), in relation to the reference data and their respective comparative that allows observing their behavior based on their energy consumption.

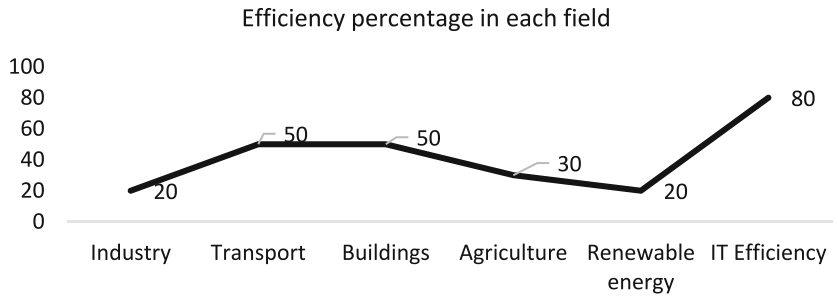

Fig. 2. Percentage Energy Efficiency of each field

Table 10. The latest advances in motion sensor technology

Sensors	Technology	Characteristics	Range (meters)	Ref.
Thermal imaging sensor	Based on the detection of infrared radiation emitted by the objects	Allows motion detection even in total darkness	20 m	[58], [59]
Radar sensor	Emits radio waves and measures the time it takes for them to reflect off objects	Excellent long distance detection capability. Operates in adverse weather conditions such as rain or fog	100 m	[60], [61], [62]
LiDAR sensor	Emits pulses of laser light and measures the time it takes for them to reflect off objects	High accuracy and spatial resolution. Allows the detection of 3D objects	80 m	[63], [64] [65]

Table 11. Technical characteristics of different sensors

Feature/Sensor	Voltage sensor 25V FZ0430	Voltage Sensor Module ACS712 30[a]	Voltage sensor ZMPT101B AC	Ref.
Measuring voltage	0 V–25 V	4.5 V–5.5 Vdc	50 Vac–250 Vac	[66], [67]
Supply voltage	5 Vdc	5 Vdc	5 V–30 Vdc	[68], [69]
Current range	0 A–1 A	0 A–30 A	0–3 A	[70], [71]
Output voltage	0 v–4.89 mV	185 mV	2V–5 Vac	[72], [73], [74]

Table 12. Internet of Things (IoT) and the optimization of energy efficiency by 2023

Appearance	Description	Data Collection Capability (% in 2023)	Ref.
Internet of things	It allows the interconnection of devices and sensors to collect data and make decisions in real time	80%	[75]
Energy efficiency	Able to detect dusk and dawn. Used with IoT technologies to optimize energy efficiency in various systems and applications	75%	[76]
Smart lighting	Use of sensors and IoT devices to manage and control lighting efficiently	90%	[77]
Electricity demand management	IoT application to monitor and adjust electricity demand in real time, optimizing energy consumption	85%	[78]
Monitoring of energy systems and equipment	Use of sensors and IoT devices to monitor and control energy equipment and systems, identifying areas for improvement	80%	[79]

The unique information from motion sensors allows describing important characteristics that affect temperature, frequency, voltage, detection angle, among others. Therefore, these results make it possible to describe parameters between one sensor and another, and thus establish their energy efficiency in a technical and effective way.

4 Conclusions

The results of this research, through a search string related to motion sensors and their energy efficiency, obtained 28599 potentially eligible. However, after conducting a thorough review of each article, it was determined that only 289 of them were considered potential for the study. Finally, 76 articles were identified as the main sources directly related to the topic.

Various types of detection sensors, including motion sensors, were discovered during the research. These sensors exhibited different parameters such as voltage, frequency, power, consumption, detection distance, and the algorithms they employ. Among the different types, PIR (Passive Infrared) and Microwave sensors were found to have lower energy consumption in watts per hour (w/h).

The analysis of the obtained results revealed significant characteristics regarding the PIR motion sensor. Specifically, it was discovered that the sensor with the code 85197

exhibited the most desirable qualities in terms of low power consumption (0.5 w) and a maximum detection distance of 8 m.

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Organizational Models and Information Systems

Technical and Business Risk Management in Software Startups

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Abstract. A software startup is an emerging company focused on the creation and development of an innovative software-intensive product or service as the basis for creating business value. These types of ventures begin their existence and operate in an environment of high uncertainty and high risks, with few resources, and with inexperienced teams. Being aware of both technical and business risks and managing them properly is a relevant factor for the survival of these ventures. However, there are very few studies focused on knowing how these types of risks are managed in software startups. This study presents the results of a series of qualitative interviews with founders of software startups regarded their technical and business risk management practices. The main results indicate that the risk management activities performed the most are risk identification and risk monitoring and control. Additionally, the two main strategies used to respond to the identified risk are building an MVP (Minimum Viable Product) and executing a pivot.

Keywords: Software startups · Risk management · Technical risk · Business risk

1 Introduction

A software startup is a newly created company with little or no operating history, focused on the creation and development of an innovative software-intensive product or service as a basis for creating business value [1].

Giardino and colleagues mentioned as the main challenges of these startups their scarcity of resources, being highly reactive, being, by definition, a new company with little or no operating history, being made up of small teams with little experience, relying on a single product, and begin to operate in conditions of uncertainty, with time pressure, and high risks [2].

Risk is usually defined as an uncertain event or condition that, if it occurs, has a positive or negative effect on one or more project objectives. Risks with negative effects are called threats and risks with positive effects are called opportunities [3].

Risk management is a subject that has been widely covered in the literature, both in relation to risk management in projects and at the business level, mainly in established companies. However, as Cubukcu and colleagues argue, the combination of risk management and entrepreneurship has been neglected most of the time [4].

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Software startups engage in many high-risk activities with respect to business and product development, and being aware of significant risks and managing them effectively is relevant to these startups [5]. Although there are many studies on the success and failure factors of software ventures, not much is known about risk management in this type of emerging companies.

Consequently, the purpose of this article is to report the results obtained from an exploratory and descriptive study aimed at knowing a) how risk management activities are carried out in software startups, b) which are the most relevant technical and business risks, and c) what are the actions or strategies adopted to manage the identified risks.

The rest of this article is organized as follows. Section 2 presents antecedents related to risk management models in software projects and a review of related works. Section 3 describes the methodological design of this study, indicating the research questions posed, the selection criteria for key informants, as well as the data collection, analysis, and coding procedures. Section 4 presents the results obtained, while Sect. 5 analyzes and discusses those results. Section 6 presents the conclusions and discusses future research.

2 Background

This section presents definitions of types of risk relevant to this study, and some known models of risk management. Some works related to risk management in software ventures are also reviewed.

2.1 Types of Risks

Since a software startup focuses on finding a business model focused on a software-intensive product or service, it is relevant for this study to consider both the technical risks related to product engineering and the risks related to business aspects. In this sense, Pressman and Maxim propose the following definitions [6]:

- Technical risks: threaten the quality and timeliness of the software to be produced. If a technical risk becomes a problem, implementation can become difficult or impossible. Technical risks identify potential problems of functionality to be included in the product, design, implementation, interface, verification, maintenance, and implementation technology.
- Business risks: threaten the viability of the business or the software to be built, and often jeopardize the project or product. Among these are 1) market risks (creating a product that no one really wants), 2) strategic (creating a product that no longer fits the business strategy), 3) marketing and sales (building a product that the sales force does not know how to sell), 4) financial (not maintaining sources of financing until sufficient income is generated).

2.2 Risk Management

One of the best-known risk management models is the one proposed by the PMBOK [3, 7], which consists of the following activities:

- Management planning: aims to develop the overall risk management strategy, decide how risk management processes will be executed, and integrate risk management with all other management activities.
- Identification: aims to identify all known risks to the project objectives.
- Qualitative evaluation: its purpose is to evaluate the characteristics of the individually identified risks and prioritize them based on agreed characteristics.
- Quantitative Assessment: Provides a numerical estimate of the overall effect of risk based on current plans and information, when risks are considered simultaneously.
- Response Plan: The objective is to determine the set of actions that will improve the chances of success of the project while meeting the applicable project and organizational constraints.
- Monitoring: its purpose is to track the identified risks, monitor residual risks, identify new risks, ensure that the response plans are properly executed and evaluate the effectiveness of their application.

Other models, such as ISO 31000:2018 [8], IEC 62198:2014 [9] and COSO ERM (Enterprise Risk Management) [10], also propose a similar set of risk management activities (with some differences in the number of activities). However, since these models and frameworks require a level of resources and dedication that are certainly not available in startups of any nature (not only software ones), the PMBOK model and its associated activities were taken as a reference for this study.

2.3 Related Works

Cobukcu and colleagues [4] have reported a case study of startups that have implemented Lean Startup principles in their product development to reduce uncertainties and manage associated risks. The authors conclude that when start-ups implement lean principles, their success rate increases drastically, because they give the required importance to both customers (market) and to the product. Additionally, these authors mention that two identified strategies (although not the only possible ones) to reduce risks are the creation of a minimum viable product (MVP) and executing pivots.

Kazemi and colleagues [5] report the results of a study aimed at characterizing how startups identify, manage, and control different types of risks during the development of their software products. They based their study on an online survey answered by 89 startups at different stages of development. Among their findings, they mention that the perception of their risk exposure decreases as the ventures advance from their early stages to more consolidated stages. Another relevant finding refers to the fact that team brainstorming is the most common risk identification method, followed by interviews with experts. The more formal methods of risk identification, for example, root cause analysis and the Delphi technique, are rarely used.

Wang and colleagues [11] report the results of a secondary study based on empirical data obtained from a large-scale survey to software startups around the world, conducted between 2013 and 2014, including responses from 4,100 software startups. Without precisely calling it “risks”, this study identifies a series of challenges that software startups often face at different stages of development. Among the main “challenges” they mention building the product, attracting customers, financing, defining the correct business model, team training, and market-product fit.

Cantamessa and colleagues [12] did a study from a repository of 214 post-mortem reports of failed software startups. Since the materialization of some risks can lead to failure, this study is particularly valuable in this regard. The authors identify the following reasons for the failure of a startup: wrong business model, running out of financing, no product-market fit, few customers, and poor market positioning.

3 Methodological Design

An essentially qualitative approach was adopted for this study. The methodological design consisted of the definition of the research questions, the selection of the key informants, the elaboration of the data collection instrument, its application in semi-structured interviews, the critical reading and coding of the answers obtained, and the analysis and interpretation of the results.

3.1 Research Questions

Based on the risk management model presented in the previous section, the research questions (RQ) posed for this study are:

- RQ1: To what extent are the usual risk management activities carried out in software startups?
- RQ2: What are the methods used for risk identification?
- RQ3: What are the main technical and business risks that usually affect software startups?
- RQ4: What are the strategies usually adopted to manage the identified risks?

3.2 Key Informants

A key informant is a source of expert knowledge of the subject under investigation, and because of their personal skills or position within a society is able to provide more information and deeper insight into the phenomenon under study [13].

For this study, founders of software startups were selected as key informants.

3.3 Data Collection

Data collection was done through semi-structured interviews to the founders of the participating ventures.

A questionnaire was prepared to be used as a guide for conducting the interviews and so as not to omit any relevant information. Questions in this questionnaire are directly related to the research questions mentioned above, in addition to a preamble with demographic questions about the participating enterprises and the key informants interviewed.

The questionnaire was previously validated through pilot interviews with founding partners of two ventures to verify the relevance of the questions and determine if they aimed to obtain the information required to answer the research questions. The questionnaire and the transcripts of the responses can be obtained from the first author.

3.4 Reading and Coding Responses

After each interview, what was said by the interviewee is transcribed, while verifying whether the answers provided ensure that the necessary information has been obtained to answer the different research questions posed. If any inconsistency or lack of adequate response was detected, the corresponding key informant was interviewed again to obtain and complete the necessary information.

4 Results

In this section, demographic information of the participating startups is presented, and the results obtained from the data collection interviews are described.

4.1 Participating Software Startups

During the data collection stage (May and June 2022), interviews were conducted to founding partners of eight software startups at different stages of development, as shown in Table 1. The participating startups have been or were being incubated at the Center for Innovation and Entrepreneurship (CIE), the university business incubator of Universidad ORT Uruguay (https://cie.ort.edu.uy).

Table 1. Participating startups and their founders

Name	Stage	Number of founders	Training
CIE1	Graduated	3	Systems engineer
CIE2	In incubation	2	Civil engineer, Economics student
CIE3	Graduated	2	Graduates in Systems
CIE4	Graduated	2	Students of Technology Analyst
CIE5	In incubation	3	Students of Systems Engineering, Management and Administration, Technology Analyst
CIE6	Graduated	3	Industrial engineer (2), Chemical engineer
CIE7	In incubation	1	Systems engineer
CIE8	In incubation	3	Systems engineer

Although a larger number of software startups were contacted to be part of this study, only the eight that finally participated had time available to grant the interviews within the period available to the authors to carry out the study.

Table 1 also shows, for each participating venture, the number of founding partners and their degree training or studies carried out prior to the formation of the respective venture. “Graduated” means that the venture successfully completed the incubation process and now operates normally in the market, while “In incubation” means that the venture is still in the incubation process in the business incubator.

4.2 Risk Management Activities

The risk management activities asked in the interviews refer to those proposed by the PMBOK, mentioned in Sect. 2.

Table 2 shows the summary of results where, for each participating startup, it is indicated whether it carries out management activities.

Table 2. Risk management activities

Startups	Plan Risk Management	Identify risks	Perform risk analysis	Plan and implement risk response	Monitor risks
CIE1	Yes	Yes	Yes	Yes	Yes
CIE2	No	Yes	No	No	Yes
CIE3	Yes	Yes	Yes	Yes	Yes
CIE4	No	Yes	No	No	No
CIE5	No	Yes	No	No	Yes
CIE6	No	No	No	No	No
CIE7	Yes	Yes	No	No	Yes
CIE8	No	Yes	No	Yes	Yes
	Yes/No	**Yes/No**	**Yes/No**	**Yes/No**	**Yes/No**
	3/5	**7/1**	**2/6**	**3/5**	**6/2**

The last row of Table 2 shows the number of startups that Yes/No carry out the management activity referred to in the respective column. The results show that the identification and monitoring of risks are the two activities that are carried out the most, while the qualitative and quantitative analysis of the identified risks are the activities that are given less importance. Additionally, only two of the eight participating startups (CIE1 and CIE3) carry out all the risk management activities.

4.3 Risk Identification Methods

Risk identification is a critical step in the overall risk management process. Risks that are not identified cannot be managed, and no matter how effective other aspects of the risk management process are, failure to identify risks undermines the process as a whole [14].

Table 3 shows the different methods mentioned by the interviewees and the number of startups that say they use them.

From Table 3 it appears that brainstorming and consulting experts are the two most used methods for risk identification. On the other hand, CIE6 does not use any of the methods indicated in Table 3. In fact, it is the only participating venture that does not carry out any risk management activity, as shown in Table 2 and, therefore, its answer to the question of what methods uses to identify risks was “None”.

Table 3. Risk identification methods used

Startups	Brainstorming	Expert consultation	Root cause analysis	Prioritization of problems	SWOT analysis
CIE1	X	X	X	–	X
CIE2	X	–	–	X	–
CIE3	X	X	–	–	X
CIE4	X	–	–	–	–
CIE5	X	X	X	X	–
CIE6	-	–	–	–	–
CIE7	X	–	–	–	–
CIE8	X	X	–	–	–
Totales	**7**	**4**	**2**	**2**	**2**

4.4 Technical and Business Risks

Based on the definitions of technical and business risks presented in Sect. 2, questions were asked about the main risks of one type or the other that have been identified. Tables 4 and 5 show, respectively, the main technical and business risks mentioned by the interviewees, together with the number of times they were mentioned in the total number of interviews.

Table 4. Identified technical risks

Technical risks of the product	Mentions
Not identifying required functionalities	5
Lack of knowledge in technologies	4
Integration to other platforms	4
Use of outdated technology	3
Others	4

4.5 Risk Management Strategies

Risk management strategies refer to actions that enterprises adopt with the purpose of mitigating, eliminating, or transferring all or some of the identified risks. Table 6 shows that the most widely adopted strategy is to develop a Minimum Viable Product (MVP), followed by carrying out a pivot.

A pivot refers to a course deviation specifically designed to test and validate a new hypothesis about a product, market, business model, and growth engine, while an MVP is

Table 5. Identified business risks

Business risks	Mentions
Running out of funding	5
Product-market mismatch	4
Loss of business opportunity	4
Integration of the entrepreneurial team	3
New competing product	3
Wrong business model	2
Others	3

a version of a product that allows the entrepreneurial team to collect the greatest amount of validated learning about customers with the least possible development effort [15].

Only one startup, CIE6, takes a different approach, which consists of outsourcing some aspect of business management or product development.

The last row of Table 6 shows the number of startups that Yes/No adopt the risk management strategy referred to in the respective column.

Table 6. Risks management strategies

Startups	MVP	Pivoting	Other
CIE1	Yes	Yes	–
CIE2	Yes	No	–
CIE3	Yes	No	–
CIE4	Yes	Yes	–
CIE5	Yes	Yes	–
CIE6	–	–	yes
CIE7	Yes	No	–
CIE8	Yes	No	–
	Yes/No	**Yes/No**	**Yes/No**
	7/1	**3/5**	**1/7**

5 Discussion

Research question RQ1 refers to knowing to what extent the different risk management activities are carried out. The results shown in Table 2 indicate that only a minority (two out of eight) of the participating startups carry out all risk management activities, from making a management plan to monitoring of risks.

Most of the enterprises assign importance to the identification of risks and their monitoring and control. This, in principle, seems to be a curious result, since of the six that say they monitor and control risks, only three of them mention that they plan the responses to the identified risks. Since the monitoring and control activity has the purpose of ensuring that response plans are properly executed and evaluating their effectiveness within project constraints, it is understood that this activity is done in a very informal and intuitive manner.

Since risk identification is the predominant activity carried out by the participating enterprises, research question RQ2 delves into the methods used to carry it out. As shown in Table 3, the preferred methods are brainstorming, used by seven of the eight ventures, followed by consulting experts, used by four of them.

Considering that, for example, Pritchard [16] presents 17 methods to carry out this activity, the fact that the interviewees have mentioned only five and with little use of three of them, shows an important limitation in the way of identifying risks. Surely, they are chosen for being well known and the simplicity of their application, but this strongly limits the way of analyzing the various sources of risks in software ventures.

This result also agrees with that of Kazemi and colleagues referred to in Sect. 2 in that brainstorming and consulting experts are the preferred methods of risk identification in software startups.

Research question RQ3 refers to the main technical and business risks that usually identify and affect software ventures. These risks, shown in Table 4 and Table 5, are the most mentioned by the interviewees. Both lists, without being exhaustive, include some risks that, in the studies by Wang and colleagues, and by Cantamessa and colleagues referred to in Sect. 2, are mentioned as factors that contribute to the failure of ventures.

Finally, research question RQ4 refers to the strategies or actions adopted by startups to manage the risks identified above: creation of a Minimum Viable Product (MVP) and execution of pivots. The creation and evolution of an MVP helps align the product under development with the needs of potential customers and focus on the target market segment. This strategy aims to mitigate or avoid both the technical risks of product engineering (for example, not identifying required functionalities, lack of knowledge in technologies, shown in Table 4) and business risks (running out of financing, product-market mismatch, or incorrect business model, shown in Table 5).

The strategy of executing pivots also helps to mitigate or avoid both types of risks, depending on the type of pivot that is adopted. In a previous study it was found that the most used types of pivots in software startups are technology, value capture, team, and customer segment [17].

These two strategies, on the other hand, coincide with the findings of the study by Cobukcu and colleagues mentioned in Sect. 2.

6 Conclusions and Further Work

As mentioned in the Introduction section, software ventures are created and developed in an environment of high uncertainty and high risk. Thus, it was reasonable to think that risk management, particularly negative ones, is a process that is actually carried out. The results obtained show that risk management is considered important, but the execution of management activities is carried out in a very uneven way.

Regarding risk identification, although there are a wide variety of methods available, only two methods – brainstorming and consulting experts – are usually used in participating startups.

On the other hand, developing an MVP and defining and executing pivots are the two preferred strategies to manage the identified risks, either to mitigate or to avoid them.

As of the results obtained may be due to influences from the incubator where the participating ventures were started, as a future work we plan to replicate this study with software startups incubated in other incubators. Regarding CIE6, its founders do not carry out any risk management activities and do not have a background in business and IT. However, it successfully completed the incubation stage and is operational on the market. For this reason, CIE6 deserves a specific case study.

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The Impact of Insufficient Organisational Change Management on Enterprise Resource Planning Benefits: A South African Case Study

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Abstract. Organisations continue to disregard the importance of adopting Organisational Change Management (OCM) when implementing Enterprise Resource Planning (ERP) systems, even though OCM is deemed a critical success factor. This research demonstrates how insufficient OCM leads to compromised ERP benefits. Two case studies, SAP Success Factors and Dynamics 365, within one organisation were selected for the research. A qualitative research approach was used to develop a framework that shows how insufficient OCM leads to compromised ERP benefits. The empirical research findings show that OCM activities that were insufficient in the ERP implementation were from an awareness, desire, knowledge, ability, and reinforcement perspective, leading to compromised benefits from an operational, managerial, infrastructural, and organizational perspective. The research contributes to theory by proposing a novel framework that highlights the impact of the ERP benefits from an OCM perspective. From a practical perspective the study can guide the prioritisation of OCM in organisations implementing ERP systems.

Keywords: Organisational Change Management (OCM) · ERP · Information System Implementation · ERP Benefits

1 Introduction

Organisations are continually investing in Enterprise Resource Planning (ERP) systems, intending to stay abreast and adapt to changing technology demands [1]. ERP systems enable organisations to have a competitive edge within the industry by ensuring that they are aligned with best practices and assisting with optimising business processes [2]. Implementing ERP systems requires a significant investment in technology and changes in business processes [3].

Organisational change management (OCM) is an approach that enables organisations to manage the transformation of the change process from the current state to the future desired state, intending to empower stakeholders to adapt to new business processes, and technologies and further manage the impact on people [4]. OCM is a critical success factor for ERP outcomes, it enables organisations to realise system benefits and

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mitigate potential issues from the implementations [5]. An inadequate understanding of the change impact and the readiness for change are key reasons why ERP implementations fail [6]. Change factors commonly compromised and leading to insufficient OCM include low engagement with stakeholders, poor communication, and the lack of leadership [7]. This research aims to explain the impact of insufficient OCM on ERP benefits by answering the following research question: *How does insufficient organisational change management lead to compromised ERP benefits?*

After a summarized literature review and elaboration of the research methodology, this paper describes the selected cases, namely the implementation of SAP Success Factors and Dynamics 365. It then presents the key findings and proposes a consolidated framework to show how insufficient OCM leads to lack of ERP benefits realization. The conclusion summarizes the findings and includes the limitations of the research and opportunities for further research.

2 Literature Review (Summary)

ERP systems empower organisations to integrate, optimise, and automate business processes, ensuring alignment with best practices, which in turn supports making informed decisions and reducing operational costs [8]. ERP systems yield various benefits, and it is critical to identify the expected ERP benefits as a measure of success [9]. Benefits management is a viewpoint that emphasises benefits as a key driver for the changes within the organisation [10]. Diverse benefit frameworks have been developed to identify ERP benefits and further group the benefits into specific dimensions, categories, and characteristics [8]. Staehr et al.'s [11] **ERP benefits** classification proposes five main benefit dimensions, namely operational, managerial, strategic, infrastructural and organizational. Staehr et al.'s [11] **ERP benefits** classification was used as a high-level structure to organise the literature themes. These were elaborated by further interrogation of the literature (see Table 1).

OCM is an approach that enables the organisation and its stakeholders to adapt to new business processes, technology, and culture [12]. The success of implementing ERP systems critically depends on OCM [13]. This paper used the **ADKAR model** to classify the OCM factors that are required when implementing ERP systems. The ADKAR (Awareness, Desire, Knowledge, Ability, and Reinforcement) model [14] aims to transition the organisation from its current state to the future desired state by promoting awareness, creating a desire for change by communicating the need for change, and emphasising why the change is required. Transitioning from the current state through knowledge and the ability to move from one state of change to the other, is achieved by providing training and upskilling resources. A third focus is on reinforcing the change, promoting, and encouraging individuals to a new way of working. When the change process is not managed, there tends to be resistance to the change which impacts the outcome [15]. Up to 70% of change programs fail due to insufficient OCM [16]. The organisations' leadership team must be educated on the value of adopting change management when implementing ERP systems [1]. Table 1 also includes the OCM themes [14]. This thematic table guided the subsequent analysis.

Table 1. ERP benefits and OCM thematic table.

Construct	Benefits Dimension	Benefit Categories	Literature sources
ERP Benefits	Operational	Productivity improvement	[10, 11, 17]
		Automation	[10, 17]
		Data Quality	[1, 11]
	Managerial	Improved decision making	[8, 10, 11]
	Strategic	Internal Integration	[2, 11]
	IT Infrastructure	Business Flexibility	[9, 11]
		Innovation	[10, 11]
	Organisational	OCM	[2, 4, 11, 12]
Construct	ADKAR	Themes	Literature sources
Organisation Change Management	Awareness	Communication	[17]
	Desire	Leadership support	[2]
	Knowledge	Training	[12]
	Ability	Support	[6, 18]
	Reinforcement	Embedding the change	[18]

3 Research Methodology

This section describes and justifies the research process. An interpretive approach was adopted as it aims to understand the impact from a human perspective and values subjective interpretations. A case study approach was used as it focuses on a relevant, current phenomenon with a practical context, and can provide in-depth insights into a phenomena through gaining a deeper understanding of how and why certain experiences occur [19]. The case studies are two ERP system implementations, within one single organisation. They were implementations of SAP SuccessFactors and Dynamics 365 respectively. These two ERP implementations are relevant case studies to address the research problem, as both these ERP systems have recently been implemented and yielded diverse benefits and changes to the organisation. Consent to conduct research within the organisation was obtained and the research was approved by a University Ethics in Research Committee.

Secondary data collected from the organisations' project repository included lessons learned from project implementations, concept briefs, and training documents (S1-1 to S2-3). The primary data collected was semi-structured interviews guided by an interview protocol with open-ended questions that is available from the researchers. The research participants were informed that the interview is voluntary and that they could end it at any point. Most interviews were conducted online on Microsoft Teams from February to October 2022 during the COVID-19 pandemic. A purposive heterogeneous sampling strategy aimed to identify diverse participants with high levels of knowledge and experience. Table 2 provides a demographic summary of the research participants.

The ten interviewees' roles include end-users, executives, business owners, project managers, and change managers, they were predominantly middle and senior managers with substantial work experience.

Table 2. Demographic profile of interview participants.

Participant ID	Age	Business Role	Education level	Management level	Work Experience (Yrs)	Years at org. (Yrs)	Case ID
P1-1	31–40	Business Analyst	Diploma	Middle	15–20	0–5	C1
P1-2	51–60	Project Manager	Diploma	Senior	31–40	15–20	C1
P1-3	31–40	End-user	Honours	Middle	15–20	10–15	C1
P1-4	51–60	Business Owner	Masters	Middle	31–40	10–15	C1
P1-5	51–60	Business Owner	Honours	Senior	31–40	10–15	C1
P1-6	41–50	End-user	Diploma	Middle	21–30	0–5	C1
P2-1	31–40	Business Analyst	Honours	Middle	10–20	10–15	C2
P2-2	41–50	Business Architect	Honours	Senior	21–30	10–15	C2
P2-3	51–60	Change Manager	Honours	Senior	31–40	10–15	C2
P2-4	51–60	Project Manager	Diploma	Senior	31–40	10–15	C2

The interviews and documentation were analysed using the Braun and Clark [20] six phase thematic analysis framework. The NVivo tool was used in the thematic analysis. An inductive approach was applied to develop a theory from the data collected. Preliminary sub-themes were collected and iteratively revised and grouped under themes. Themes were then grouped under ADKAR components and ERP Benefit dimensions. Both classifications were found to be sufficiently broad to incorporate all themes. Having triangulation of data, in both interview and secondary data helped confirm themes. Different versions of the NVivo project were saved as the coding progressed, so an audit trail of analysis is available.

4 Case Descriptions

The case organization is a leading insurance company in South Africa, with a growing international footprint. They have over six thousand employees and conduct business with intermediaries and direct clients (S2-3). The organisation continuously invests in

technology, as technology facilitates efficiencies and promotes decision-making. They had been using on-premise SAP modules and made a strategic decision to invest in SAP SuccessFactors, a cloud-based Human Resources talent management enterprise system (**C1**). The organisation aims to gain competitive advantage by constantly attracting, motivating, and retaining talent (S2-2). They implemented the following modules from 2018 to 2022: Talent module, Onboarding, recruitment, Performance and Goals, Compensation, and Learning. Onboarding and Recruitment were implemented first. The second case (**C2**) refers to Dynamic 365 (D365). The Organisation partnered with the D365 team to implement an ERP and customer relationship management (CRM) intelligent business application (S2-1). The implementation of the D365 supports the organisation's strategic intent of investing in technology to drive operational efficiencies and data for strategic decision-making (S2-1). D365 has been implemented for various departments within the organisation, according to the respective departments' requirements. The first implementation was in 2020. The organisation recently implemented the field service and power apps functionality to enable surveyors to effectively manage the surveyance process (S2-2).

5 Findings and Discussion

This section explains the key findings elicited from the data collected from both cases. The paper analysed ERP benefits and how they are compromised, furthermore analysed what OCM factors are compromised with ERP implementations, and finally analysed how ERP benefits are impacted by insufficient OCM factors.

5.1 ERP Benefits

ERP implementations yield countless benefits for organisations. The research participants shared the ERP benefits which were realised and compromised. To illustrate the responses and data analysis, one of the dimensions, namely the **operational benefits**, are explored in more detail. A detailed analysis of all other themes is available from the authors. Table 3 provides list benefits elicited. In the tables in this section, the sources represents the number of data sources and the mentions represent the number of text extracts referring to each theme.

The operational benefit dimension had eight sub benefits or themes. The **data and operational efficiency** theme had the highest number of references. The research participants shared varied insights about the data benefits of the ERP systems. The key findings from the data theme included the availability of data, the usage of the data, and the quality of the data. The research participants advised that ERP benefits from a data perspective were compromised from an availability, usage, and quality perspective. An interesting concept was shared that organisations are constantly in need of data, however, when people are provided with the data in real-time, they are overwhelmed by the level of data available, and the users are challenged on how to effectively use the available data. *"People are overwhelmed by the amount of new data available to them. There's also the case of the fact that now it is exposed for the first time, so people are a little bit in denial in saying, do I want to believe this? So, there's also that thing of can the data*

Table 3. ERP Benefits themes.

Benefit Dimension	ERP Benefits Main & Sub-themes	Sources	Mentions
Operational	Productivity	3	5
	Operational Efficiencies: Duplication in process; Manual interventions	8	20
	Central Repository	3	5
	Data: Overwhelmed by the data; Data not effectively used; Data quality	8	33
	Process Automation	4	4
	Ability to Track	7	15
	Transparency	5	13
	Improved User experience	5	13
Managerial	Reporting: Low-quality reports; Resorted to manual spreadsheets; Lack of understanding; Reports not available	5	11
	Decision making: Predictive analytics was challenging	2	7
	Creating Business Value: Business needs not met	1	6
Strategic	Strategic Alignment	3	5
	Compliance	1	1
Infrastructure	Cloud-Based Solution	3	4
	Security	2	4
	Integration	8	20
	System Functionality: Lacked understanding of the ERP functionality; Full system capability not used; Customisation led to system instability	8	26
Organisational	Standardisation of Business Processes: Standardisation led to inefficiencies	8	28

be right?" (P1-5). Furthermore, data was compromised from a data quality perspective as the data was not always accurate which therefore had an impact on how data was used to make informed decisions. *"The data available is not accurate. And the way that it was handed to them in some rudimentary report was not usable"* (P1-2). The impact of data quality issues meant that users cannot rely on the ERP as the source system. Furthermore, data was compromised as there is still a high level of manual intervention and manipulation of data for it to be effectively used. *"We had to do a manual process for calibration, you know, so you had to pull the scores out of the system, put it on a spreadsheet, look for anomalies within the ratings and then go to your Manco member as opposed to, you know if you had it in the system"* (P2-4).

The research findings align with literature on ERP data benefits that are imperative and the impact when the benefits are compromised. The quality of data in ERP systems is critical, the data must be accurate, consistent, and valid to empower decision-making [1]. Furthermore, poor data quality has an adverse impact on the benefits of implementing an ERP from business automation and, cost reduction perspective [21]. Despite the compromised benefits, the organisation realised data benefits from the ERP as the data is now available in real-time and there is an improvement in data quality levels providing the organization with good insights. *"This year was the first year that we ran annual increases and our bonus processes online, allowed us to do everything in the system and allowed us to see the data real-time"* (P1-6).

The Operational Efficiency sub-theme was the second strongest theme within the operational dimension. Operational efficiencies were compromised as they experienced a high level of duplication in process and manual interventions. Furthermore, the operational efficiency benefits were compromised due to manual interventions in managing processes and a lot of duplication of effort, which defeats the expected benefits of an ERP. *"I think people still do a lot of that on spreadsheets"* (P1-4).

Despite experiencing challenges with ERP benefits, the interviewees suggested that the implementation of the ERP has yielded an improvement in operational efficiencies from a time, cost, and quality perspective. The greatest benefit in C1 was the ability of the HR department to continue business operations during the COVID pandemic as they were conducted online. *"One of the biggest benefits to date is the fact that operationally HR could continue in COVID due to the fact that we had everything digital. If we did not have SuccessFactors in place, we would have been at a real difficulty to be able to onboard people"* (P1-5).

5.2 Organisational Change Management Activities

OCM is a critical success factor for ERP outcomes, it enables organisations to realise system benefits and mitigate potential issues from the implementations [22]. This section analyses how OCM was applied when implementing ERP systems. The research participants shared the OCM factors that enabled the successful implementation of the respective ERP systems subsequently they also expressed the OCM factors that were compromised. The OCM factors were categorised according to the ADKAR model [14] and are presented in Table 4.

As an illustration of our more detailed analysis, we discuss only the last factor (a full, detailed analysis is available on simple request). The last stage of the ADKAR model is to reinforce the change implemented by promoting the change to users and enforcing the new way of working [14]. The participants shared how the post-implementation support was compromised due to the lack of enforcing and embedding the benefits of the ERP systems as the users were still not too sure how they are benefiting from the system. *"I think one of the things that we maybe lacked was call it that after-sales service in terms of reinforcing what the benefits are"* (IP6C1). The research participants advised that the support services were not always available to support and there was no further training session post the implementation of the ERP system. *"Availability of HRSS resources for support, caused by capacity constraints on their side"*. (S1-1). *After business go live,*

Table 4. OCM activities.

ADKAR Factor	OCM Themes	Insufficient OCM	Sources	Mentions
Awareness	Communication:	Inefficient communication	7	15
		Infrequent communication		
	Stakeholder Engagement	End user not involved	5	11
Desire	Leadership Support	Lack of leadership support	4	13
	Resistance to change	Lack of buy-in	5	15
Knowledge	Training	Training material not easily accessible	8	17
		Training materials not effective		
Ability	Skills	Challenge with applying new skills	3	9
Reinforce	Post Implementation Support	Limited availability of support	9	40
		User adoption challenge		

have those additional training sessions available for those who are still struggling" (IP1C1).

Another theme which emerged from the reinforcement theme was user adoption. The research participants expressed how challenging the adoption of the two ERPs was. The adoption process tends to take longer when OCM is not effectively applied [6]. *"Every time that you provide them with training, it takes time for them to adopt and learn the system and to be fully functional in the system with its capabilities"* (P1-2). The low adoption rate was due to the lack of ownership of the ERP system from a business point of view. The ERP systems were based on their requirements. Yet, when the ERP system was implemented, they failed to take ownership.

5.3 Impact of OCM on ERP Benefits

Based on a more detailed data analysis, we propose the following model which summarizes and shows the relationship between insufficient OCM and compromised ERP benefits (Fig. 1). The model is adapted from the ERP benefits framework by Staehr et al. [11] and the ADKAR States of Change model [14].

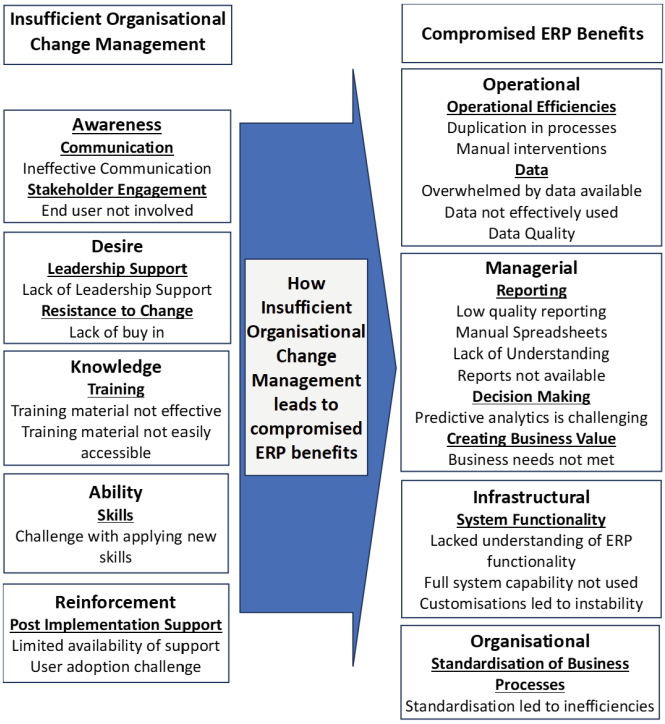

Fig. 1. Proposed Model: Impact of insufficient OCM on ERP benefits.

6 Conclusion

This paper aimed to explain how insufficient OCM leads to compromised ERP benefits. This was achieved by determining which ERP benefits are compromised, the OCM activities that were insufficient when implementing ERPs, and finally finding the relationship on how ERP benefits are compromised due to insufficient OCM. A qualitative research approach was followed using two ERP implementation case studies in a single organization. The following ERP benefits were compromised: operational efficiencies, data, reporting, the decision-making process, the opportunity to create business value, the ERP system functionality, and the standardisation of the business process. From an OCM perspective, the findings described how OCM activities were applied during the ERP implementations and activities that were insufficient, thereby compromising benefits. Benefits were compromised due to ineffective communication, lack of stakeholder engagement, lack of buy-in, ineffective training, lack of planning for late adopters, and limited post-implementation support.

The research contributes to theory. The research emphasizes how ERP benefits are compromised because of insufficient OCM. We propose a novel framework that highlights the impact of the ERP benefits from an OCM perspective. These findings also have practical implications. For project sponsors, project managers, and change managers we highlight the impact of insufficient OCM when implementing ERP systems

from a reduced benefit perspective. This study can hence be used in business cases arguing for the prioritization and hence funding of relevant OCM activities during ERP projects. The OCM activities having the largest impact can be prioritized.

The research has limitations. It consisted of two case studies in one single organization - a large international financial services organisation. Secondly, the sample size was relatively small as only ten (though senior) research participants were interviewed, and a limited set of documents were used. Hence broad generalizability of these findings can't be argued especially to dissimilar organisations. In addition, only broad relations between OCM and ERP benefits are described in this study. Future research could be conducted with multiple organisations as case studies, and possibly with more interviewees and documents to further understand how insufficient OCM impacts ERP benefits. Stronger relations between individual OCM factors and ERP benefits could then be explained. The suggested future approach will provide a distinct perspective on the phenomenon. This would allow a validation of the model proposed in this paper, and possibly its generalization to a wider context.

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Infrastructure Overlays and Digital Chimeras: Keys for Reading Information Infrastructures

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Abstract. The paper studies the relationship between infrastructures and their corresponding *information* infrastructures. It introduces the concept of infrastructure *overlay*, *i.e.*, a generic object that encapsulates complexity within an infrastructure, and of *digital chimera*, *i.e.*, for any given overlay *instance*, the collection of its representations in the information systems of actors that own, use, or for some reason encounter the instance in the infrastructure. Examples are the *container* overlay in cargo infrastructures and the *interbank transfer* overlay in financial infrastructures. Overlays exist in a world where goods and assets are transported or traded, *i.e.*, the *analogical* world. What can be said about their *digital* alter-egos, partitioned, distributed among a number of information systems, and managed piece-wise according to heterogeneous rules? Based on two cases that unrolled in Swiss agriculture between 2016 and 2019, and on the subsequent study of *dependencies* between information systems, of digital dependency *feedback* to information system operators, and of the notion of *shared distributed functionality*, the paper defines a conceptual framework within which actors and information systems can be meaningfully positioned in an infrastructure relatively to analogical *objects* and their digital *representations*. The paper presents several overlay-chimera pairs with different characteristics and clarifies the role of software-based platforms that have been proposed as the building blocks of information infrastructures. It suggests that overlays should be designed (or, in case that they seem to already exist, should at least be well identified and understood), *before* their digital chimeras are developed and deployed at large.

Keywords: Infrastructure overlay · Digital chimera · Service platform · Shared distributed functionality

1 Introduction

This paper defines a conceptual framework where (analogical) actors, (digital) information systems, and (software-based) platforms [1] can be positioned relatively to generic objects in infrastructures and their representations in information infrastructures (IIs). To support this seemingly paradoxical perspective, it introduces the notions of infrastructure overlay and of digital chimera. An overlay is a generic object (like a class in

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programming terminology [2], but we consider here the analogical world) that hides some form of complexity in an infrastructure. For example, the container [3] overlay in cargo infrastructures, that we will develop below. There might be thousands of actual instances of the generic model of a given overlay in an infrastructure, or millions as for containers. The chimera of an overlay instance is the collection of digital representations of the actual object, that may exist, or subsist, in information systems (ISs) operated by entities that have, or have had, something to do with that instance. For example, a digital representation of any given container that is on its way from Shanghai to Los Angeles exists in the IS of the shipper, of the transporter, of the insurer and of the banks involved, of customs authorities, of the recipient, etc. The instance's chimera is the collection of these digital representations. Each representation has its own structure, contents, meaning, purpose, etc. Though each one is consistent within its host IS, considered as a collection they are not in general mutually consistent. They look like a mythological beast, a patchwork of heterogeneous digital limbs and organs.

The distinction and the frontier between the analogical and digital realms is fundamental to understand dependencies in the context of the digital transformation. Notions such as person, property, control, or responsibility belong to the analogical world, as does anything material like a building or a human being. Some analogical entities, that we call actors, have the legal right and responsibility to operate "digital" information systems, *i.e.,* analogical artefacts that are gateways between the analogical and the digital worlds. This digital level, a boundary object [4], is the interface of the analogical world with the digital world. On the other side of this frontier resides the infinite set of binary words among which a small portion can be meaningfully interpreted by an actor using the IS it operates. One same digital word (say a given 15MB sequence of bits among the 2120′000′000 binary sequences of that size that exist in the digital world) might be meaningful to several actors, but have different, possibly inconsistent, or totally unrelated, interpretations.

Actors *interact*. Interaction between two actors may generate *dependencies* between the two. If the *IS*s that they operate respectively interoperate, these systems might also be interdependent. Some of the latter dependencies are purely of a technical nature (like the usage of a service API that generates a client-server dependency between the calling system and the server). Dependencies between systems can then feed from the digital level *back up* to the level of the actors, in new forms that the latter might not want to accept. If different actors, possibly competitors, share objects and common functionalities in an infrastructure (for example implementing the end-to-end transport of a container), is it necessary, useful, desirable, or even *possible*, to maintain some degree of consistency within the chimera of the corresponding overlay instance? The answer to this question is rooted in the roles and dependencies of the actors that are concerned by the overlay, in the ways they interact, and in the ways their respective *IS*s interoperate.

The study of information infrastructures pertains to the discipline of Science and Technology Studies (STS). STS scholars conduct case studies in the contexts of *e.g.*, *Platform studies*, *Internet studies*, or *Information systems* [5]. Targeted field work tends to *blur* the generality of information infrastructures relatively to the *II* of the infrastructure where the study is conducted (*e.g.*, healthcare, transport, or energy). On the other hand, computer scientists and engineers tend to be solution oriented. A problem

will be identified in a socio-technical setting, and a technical solution will be developed that resolves *some* sub-problem within an *arbitrary* set of constraints. The solution (*e.g.*, relational databases for information management in the early 1990's) might then splinter into different approaches and spawn a multitude of applications that spread across the infrastructure and generate an *installed base* [6] in the related *II*.

This paper results from a collaboration between a computer scientist in distributed systems and a scholar in STS who works on the dynamics of digitization in society. It is based on a fieldwork conducted during 2018–2019 in relation to the digitization of Swiss agriculture, and on the development of two system architectures between 2016 and 2019. Our paths crossed during the second of these projects. We have since then worked to understand the socio-technical mechanisms underlying the development of information infrastructures. Confronting our preconceptions on fuzziness and narrow determinism, we achieved formalizing the distinction between the levels and the roles 1) of actors in society and 2) of the digital information systems that these actors operate, and to study at these two levels dependencies [7], shared distributed functionality (*SDF*) [8], and the analogical overlay-digital chimera dichotomy discussed here.

In the next section we use the two cases in Swiss agriculture to illustrate the basic concepts of the paper. In Sect. 3, we develop a series of examples that apply these concepts in different conditions. Infrastructure overlays are unnumberable, and we recommend the reader to do this exercise on their own with examples of their choice. Section 4 discusses the conceptual framework and we conclude in Sect. 5.

2 Two cases in Swiss Agriculture

Between 2015 and 2019, Swiss agriculture was under strong pressure to digitize. Authorities argued that digitizing farms would increase profitability and reduce ecological footprint. Administrations that managed subsidies to farmers were sorting out a plethora of data and applications. In the economy, digitization was supported by many players. Digitization initiatives were emerging, intertwined with alliances, interests and power relations, at sectoral or transversal, local or national -even international, levels. Farmers remained skeptical. It seemed more urgent to reduce the number of measures and the administrative burden that had grown steadily over the years, to the point of putting them at risk of errors and sanctions [9].

Amidst this turbulence, two projects named TIP and ADA, involved farmers associations, and incidentally, the first author in the role of solution's architect. The second author followed the ADA project. In the course of her ethnographic fieldwork, which lasted from May 2018 to July 2019, a collection of materials was produced on which the contextual description of this section is based. They recount the journey of the ADA project from its first conceptual inspirations in 2016 to its entry into production in the form of an operational prototype in July 2019, and include: i) every document produced- and ii) every e-mail exchanged-, during the project; iii) a corpus of press articles published on the project by the agricultural press; iv) verbatim transcripts of project-team sessions and of interviews conducted by the ethnographer with the architect, with members of his team, and with over 40 actors in the sector (farmers and organization leaders); and v) field diary notes (160,000 words, 725 pages, and 223 entries) taken by the ethnographer

throughout her investigation. The following subsections describe the two projects TIP and ADA and introduce, for each one, the overlay involved and the underlying conflict within the sector for the control of their chimeras.

2.1 TIP: The Individual Animal Overlay

The first project concerned the individual traceability of pigs. In Switzerland, large supermarket brands control the transport, the slaughtering, and the processing of animals, but not the producers. Grouped into label production associations, the latter can choose whom to sell their animals to and some practice on-farm sale. Authorities require batch identification of litters, but since all the animals in a batch share the same identity, it is useless for traceability. The distribution chain is digitized downstream from the slaughterhouse to the supermarket shelf, but no backward link subsists to the animal's origin.

In 2016, a major distributor decided to introduce an electronic unique identification for its labeled pork producers. Each animal would be tagged with an RFID chip. Farms and slaughterhouses would be equipped with electronic gates to identify animals. The IT operator of the solution would collect this data on its service platform and provide access to the distributor through APIs. The latter would be able to connect the digital identifiers used downstream of the slaughterhouse with the animals bred on the farm, and incidentally to predict in real time the quantity of meat available from each farm.

Some producers were interested: by reconstructing from their birth how animals were bred, they could locate causes for rejection at the slaughterhouse (the cost of which they bore). Their association tried to communicate their objectives to the project, but to no avail. The project started raising angst: producers would be dictated what they produced, at what price, when and how; they would no longer be able to sell through other channels; not to mention the cost of equipment. Unless they were integrated into a distributor's operation, small transporters, traders, veterinarians, and even inspection bodies with which farms worked, would gradually be squeezed out of the digitized sector, reinforcing verticalization and dominance by the sector's major players.

Faced with this situation, the association decided to implement individual identification and trace of pigs *by itself*, and to make the whole sector benefit from the solution. The project, called TIP, for *Traçabilité Individuelle des Porcs* in French, was based on a *raw data bus* that would notify *events* concerning individual animals to registered actors. Producers, veterinarians, inspectors, buyers, transporters, *etc.* would code events using mobile devices that would deposit them on the bus. The bus would multicast each event to the recipients registered in agreement with the animal's owner, regulation, and the data protection rules in force. By 2017, TIP was being tested in production and in the slaughterhouse. It was stopped when it became clear that ADA -see the next subsection, had a higher priority, but the distributor's momentum had been curtailed.

Discussion. A large body of unique and identifiable objects, *i.e.*, pigs, was of interest within a sub-branch of animal production. Considering an *individual animal* as a generic object enables to *define* an overlay for animal production. It emerged after the BSE outbreak [10] of the late-1990s, when it became mandatory to trace individual cattle. The overlay is easy to grasp (an individual cow, sheep, or pig). Instances can be handled in

groups (*e.g.*, for transport, feeding, or treatments), but each instance is digitally managed individually. In the case of TIP, **significant events** in the life of an instance are coded by *registered actors* and sent to other actors according to the (business) relationship between sender and receiver. A *breeder* initially **tags** the animal and **sells** it to a *farmer* who **buys** it (two ordered events), cares for it and registers occasional events (**weighing**, **transport**, **sale**); the *veterinary* mandatorily informs the *authority* about **treatments** or **diagnosis** of disease; the *trader* **buys** and **resells** the animal to a *retailer*; who **transports** it to the *slaughterhouse* where it is **culled**, **examined**, and either **rejected** or **processed**, *etc.* An animal's *digital chimera* is *the* distributed collection of events related to that instance, that are maintained by some actor in the *IS* it operates. Each actor controls only the portion of the *chimera* that contains events of its concern, and in particular, that are related only to animals that it has business with. Each sequence of events concerning one instance is totally ordered by the flow of time in the life of the corresponding animal, so an animal's chimera is consistent (*i.e.*, it can be consistently reconstructed based on the datasets distributed in different *IS*s). The consistency property of the chimera is important in the case of livestock (*e.g.*, to trace the origin of an epizootic) and can be implemented (relatively easily). It is not necessary however to maintain a centralized chimera or a centralized database for all chimeras (as in the distributor's solution) in order for each actor to have access to the information it needs. It is necessary that all the actors involved in some relevant aspect of an animal's life (and post-mortem processing) have access to the information (*i.e.*, data) relevant to their concerns. Actors concerned with one given animal *share the functionality* that any event (registered by some actor) related to the animal is sent to the actors concerned by the event. Actors that produce events are responsible to operate systems that register their events and reliably notify them to their interested or concerned *peers*.

2.2 ADA: The *Production Unit* Overlay and Its Fully Distributed Chimera

In 2015 a project to manage agricultural data was launched by a private consortium. It proposed a single point of access to all the country's agricultural data and claimed it would meet farmers' expectations on simplifying administration. In 2017, the consortium stepped up its ambitions and proposed a commercial smart-farming platform on top of its embryonic database. Third-party systems could connect to the platform using its APIs. It was the first attempt to bring together all the public and private operators in the sector using standardized data. By then, the project was backed by the federal government, itself engaged in a Mercosur round and seeking support from the farmers.

The project was controversial, raising criticism on *feasibility*; *sustainability*; *economic model*, *cost to farmers*; and the *incongruous transition to smart-farming*, given the specificities of Swiss agriculture [11], on the case of the Swiss Jura]. It also raised concerns: the operator would have a detailed and comprehensive view of the market, leading it to capture producers and integrate them vertically. A commercial platform would enable technical and/or legal control of data and its circulation (an argument developed in the literature on Twitter [12, 13] and on Facebook [14]. The choice of services could be dictated by a player controlling all the data and concentrating the power, and lead to a cartelized market (an argument developed in [15, 16]. Private and public organizations

could be captured. As the project progressed and fears grew, two organizations proposed an alternative. Their approach, called ADA (for *Agrar Daten Austausch*, in German), aimed to connect the existing *IS*s of organizations via a peer-to-peer platform, so that they could exchange data directly, under their full control, and without changing their legacy infrastructure. The project seeked to reduce the complexity of data management where it was possible, by implementing *direct transmission of selected data between database operators, on request by the receiver, and in the format used by the sender, provided that the farmer had authorized the transmission and that the authorization was valid at the time of the request*. The solution's architecture was a fully distributed peer-to-peer platform providing peers with exactly that *SDF*.

Discussion In Switzerland the farm is the central functional, administrative, commercial, and cultural entity in agriculture. The farmer or a farm's owner are legally responsible for modes of production, results of controls, contracts, and relations with other actors. But the farm is the generic unit of production. It has become *de facto* a convenient and useful overlay of the infrastructure, used since the 19th century to collect information on agriculture[1]. The emergence of database technologies, PCs, and web-based applications only made it possible for public administrations and private organisations to collect information *directly* from every farm, which led to uncontrolled administrative burden, risks, and a growing dissatisfaction of farmers [9].

The digital chimera of a farm (instance) is a collection of heterogenous datasets, each managed by the *IS* of some institutional actor. Datasets are *not mutually consistent*, be it in time, in structure, or in contents. Interviews revealed that farmers, administrations, or service-providers *needed it to be that way* [18]. A farmer's digital field-book has a seasonal periodicity. For administrations, the processing of farm data begins in March with the closure of the online census, followed by controls *in situ*, computation of subventions, formal decisions sent to farmers, a delay for appeals, processing of eventual appeals, and finally payment, all based on data collected on the 28th of February. For a service provider that supplies semen for livestock, the preparation and delivery of samples depends on a call from the farmer or an alert from a sensor when a cow is ready for insemination. Actors have different, *mutually inconsistent*, representations of a farm, and their own requirements on *validity* (time) and *structure* (contents) of data.

A central database implies a unique, centralized chimera, accessed by third parties over a (privately or publicly) controlled service platform's API. Such an architecture and its internal database generate dependencies in favour of the owner of the solution that might throw in havoc the client-actors' processes. In ADA, on the contrary, the distributed, inconsistent, digital chimera *is not modified* by the solution; nor are *pre-existing* interactions between organizations and ways their *IS*s (inter-)operate.

[1] In the late 1800s, the Union of Swiss Farmers began to collect data on farms for statistics, extension, and political purposes [17].

3 Overlay-Chimera Examples

3.1 The *Container* Overlay in Transport Infrastructures

The container is a cornerstone of (non-bulk) cargo infrastructures and a generic object that defines a world-wide overlay. Standard Forty-foot Equivalent Unit (FEU) metal boxes (overlay instances) can be moved between ships, piers, trucks, trains, etc. A box hides the complexity of the goods stored inside, from some place of origin to a destination, leaving the process of collecting, loading, unloading, and distributing contents to local agents. The information concerning an instance and represented in its chimera is composed at least of a unique identifier, a load manifest, and an initial sequence of relays leading from sender to recipient of the shipment. Information on planned route, intermediaries that handle the box, fees for service, dangerous goods, etc. might be included, added or changed by actors involved. A container has an owner and can be leased to a transporter: the owner's representation is not identical to that of the transporter. A container's chimera is generally distributed among many actors. It changes at each relay along the route (basically a sequence of events consistent with the flow of time). A planned relay might be subject to external constraints (secured payment, provision of service, customs control, re-route to new destination, etc.) and lead to uncoordinated partial updates of the chimera. The SDF among IS operators is to generate, and to notify to any concerned peer, every relevant event concerning the instance. Unexpected events such as the loss of a container at sea during a storm [19], might provoke spontaneous inconsistencies in, and later unplanned partial changes to, the chimera.

3.2 The *Order* Overlay in e-Commerce Infrastructures (Amazon)

Consider a person living in Portugal that orders a book from amazon.es to be delivered to an address in Brazil. The sequence of events, from the selection of the book in an online catalog, to delivery at destination, including payment, possible payment or prepayment of custom fees, physical transport from some warehouse to destination, etc. is complex and involves possibly many actors. The overlay for this configuration is the order, a generic object that hides the complexity of the sequence above. An instance is initiated by the purchaser on Amazon's web-platform (which is a component of the global e-commerce infrastructure). The instance's chimera is the (distributed) collection of representations of that specific order managed by the IS of any actor involved in the sequence. What are its properties? After choosing the book, the customer first checks out, which is a complex online payment procedure that ensures an interbank transfer from the buyer's credit card account to one of Amazon's bank accounts (see below). From then on, Amazon is responsible for the timely delivery of the chosen product to the intended address. Amazon's IS manages a consistent reference-representation of the instance. At each step in the sequence of events, Amazon's platform exchanges a piece of the reference dataset with the IS of each service provider involved. Whichever representation an IS has of the order, it is consistent with Amazon's reference. Every operation on the instance's chimera is executed using Amazon's platform API. The platform (which controls revenues that amount to the GDP of the world's 30th economy) controls every individual partitioned distributed chimera of an Amazon order consistently through its central, proprietary, web-service oriented architecture.

3.3 The *Interbank Transfer* Overlay in Financial Infrastructures (SWIFT)

To transfer an asset between two banks, some actor S that owns an account AS at a bank B1 orders B1 to debit an amount a from AS and "send" a to an account AR owned by an actor R at a bank B2. The transfer can be initiated on paper, by phone or e-banking, etc. The interbank transfer is a generic object that defines an overlay in financial infrastructures, for example in Europe (*e.g.,* SEPA [20]). For a given interbank transfer instance, the chimera is initially built up at B1 and goes through a sequence of transformations, partitions, and distributions, involving B2 and an intermediary, *e.g.,* SWIFT [21]. The role of SWIFT is to guarantee that the resulting chimera will respect the rules of interbank transfers and be mutually consistent in the IS of all three participants (B1, B2, and SWIFT). In order to do this, SWIFT's IS implements a distributed atomic transaction between the three actors, that is consistent with all of SWIFT's other operations.

3.4 The *Reliable Byte-Stream Connection* Overlay in Internet Infrastructures (TCP/IP)

Consider the internet. Any pair of information systems associated with an IP-address can establish a duplex reliable byte-stream connection. The reliable connection, is a generic virtual object and the basic overlay of the Internet. The TCP protocol [22] provides reliability and consistency of every connection instance over the IP-datagram infrastructure. The chimera of an instance, at any chosen moment, is composed of the exact representation, at each sender-end of the connection, of what has been sent, and at each receiver end, of what has been received. Moreover, IP and TCP headers that describe the connection are riding on packets enroute between routers, or stored where packets have transited. The chimera is inconsistent, vaguely informative at the connection's four end-points, and controlled by no single IS. IP-hosts, who are peers in the TCP/IP interoperability platform share the functionality of reliably exchanging data with any peer, provided that both agree to connect. In order to keep a connection operational, the end points maintain some degree of mutual consistency of the chimera pieces that they manage. This is done using windows and sequence numbers, and a common standard protocol shared by every IS for the management of the connection.

4 Discussion

We set out to define a conceptual framework within which actors and information systems can be meaningfully positioned in an infrastructure, relatively to analogical objects and their distributed digital representations.

Actors have different roles, responsibilities, and concerns relatively to the instances of an overlay. A manufacturer ships goods overseas to a customer, using a container that is transported by a shipowner. At least half a dozen other actors are involved in the sequence of events that unroll from the moment the container is sealed at the plant to the moment it is opened at destination. Each actor operates an IS that manages one representation of the instance, *i.e.,* a piece of its chimera. For any actor the representation in its IS is consistent with the role, responsibility, and concerns it has relatively to the

instance. Unless an event requires that actor to interact with another, there is no need for its local representation to be consistent with the rest of the chimera. Even if some event would require the actor to interact with another in relation to that instance, their representations (gladly) are not required to be identical: the pieces of the chimera must only be consistent to the point where both information systems can interoperate in order to handle the corresponding event in compliance with relevant requirements.

When they interact in relation to an instance and their ISs interoperate, exchanging data and updating the piece of the chimera that they each control, the dependencies between systems that may arise might also feed-back into new dependencies between the actors. The examples in Swiss agriculture show how external actors (the distributor vs. TIP or the consortium vs. ADA) were seeking to take control of the chimera, in order to better control actors involved with the instance. The latter reacted defensively: breeders wanted to access the chimera (TIP) and farmers did not want to lose control of it (ADA). Other actors whose missions depended on properties of their piece of the chimeras did not want to lose control over it either. These actors were willing to collaborate to collectively maintain a chimera without losing control individually, because data management is expensive and prone to errors (TIP and ADA), or out of operational necessity (containers and SWIFT). Collaboration requires them to identify the related SFD and to implement it according to the constraints and concessions they are willing to withstand. Other overlays (*e.g.,* the e-commerce order) might require a strict central control of the chimera by an actor deeply involved (Amazon). An IS architecture must be developed to ensure this control. A centrally controlled, service platform might be chosen as the technical solution to maintain consistency of the chimera and to control overlay compliance. This has nothing to do with controlling the actors (the buyers, the third-party developers) using the platform and the information it accumulates, which might violate regulation.

Finally, time in the analogical world (flow, ordering, duration, synchronization), can be an important overlay characteristic for some actors, that must be represented in the chimera, but whose piece-wise representations might be mutually inconsistent. The question that arises then is not how to maintain the distributed chimera consistent with time (*i.e.,* to serialize it, in terms of database transaction management), which might not be possible, but how to operate the overlay, and eventually improve and expand cooperation [23], using an inconsistent chimera.

5 Conclusion

The overlays we describe in this paper illustrate the relationship between infrastructures and their corresponding information infrastructures. Overlay instances belong to the analogical world (even the TCP reliable connection overlay is analogical), whereas chimeras are digital counterparts, partitioned and distributed piece-wise among information systems operated by actors with different concerns, responsibilities and roles.

Service platforms have been proposed as building blocks to articulate information infrastructures using APIs [24]. However, the standardization of data required by the approach has proven to be an overwhelming problem [25, 26]. The overlay-chimera

dichotomy enables to articulate information infrastructures differently, by positioning actors and their information systems relatively to objects and their digital representations, rather than the other way around.

The approach opens the way to first designing (or understanding thoroughly) the overlay, and then only developing and deploying the chimera, rather than choosing a technical approach a priori (*e.g.,* a central service platform) that might not meet the constraints of some (many) actors. Considering the recurrent problems encountered by health authorities to develop and deploy electronic patient records (EPR) [25], we believe that healthcare infrastructures, for example, and their information infrastructures, could benefit from such an approach. Are the "politically correct" patient overlay in healthcare, and its chimera, the EPR, the correct choice to manage at the same time patient health and public healthcare policies? Could it be meaningful to search for distributed functionalities shared within clusters of actors, in order to identify better adapted overlay-chimera pairs?

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Handover Analysis of Mobile Cellular Network in a Populated City

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Abstract. Mobile network operators continuously monitor QoS in terms of multiple metrics to ensure high network performance. Handover (HO) is one of the key issues in cellular communication networks, as it poses multiple threats to QoS. In this work, several real measured radio frequency (RF) parameters are used to analyze handover performance using statistics and Machine Learning. The measurements were collected through Android applications in 4G mobile networks in an urban area of the city of Quito, Ecuador where the existence of nearby base stations was checked. Variables were created for the analysis, such as one indicating the existence of a handover and another indicating whether the handover was successful or unsuccessful. The results of the statistical analysis show that performance metrics determine HO problems. While Machine Learning was used to classify whether the handover was successful or unsuccessful based on certain input parameters using Decision Trees. A predictive analysis was also made using Linear Regression to determine whether handover existed or not. Finally, the machine learning models were evaluated, obtaining an accuracy of 0.73 for the decision tree and an RSME of 0.077 for the regression.

Keywords: handover · handover failure · handover analysis · RSRQ · machine learning

1 Handover Problems: Monitoring Ang Performance Optimization

The monitoring of mobile network performance metrics provides a very important reference for mobile network operators to improve the quality of service (QoS) offered to users. In [1] collected data in an urban area to comprehensively analyze mobile broadband performance. The data collected with 3G and 4G technologies measured several performance parameters such as signal quality, throughput, ping, and handover. The results present maximum average throughput, minimum average ping and loss, overall average data rate, and others to provide recommendations to operators.

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Handover (HO) is the process by which a mobile terminal changes the cell or base station to continue its communication while in motion. Since HO has adverse effect on the overall performance of wireless networks, different features and requirement are neccesary to reduce the impact of HO [2]. Also, various key performance indicators (KPIs) are used to measure how the network performs during a HO. The HOs failure rate is the number of HO failures-unsuccessful HOs-divided by the number of times the UE experienced the HOs. The HO metrics analysis is essential to ensure optimal performance in wireless networks, particularly for HO optimization [2].

In the next generation networks heterogeneous networks comprises the deployment of different cells with different sizes based on the transmitted power, and the frequency of transmission used: macrocell, microcell, picocell and femtocell [2]. Thereby, HO management is provisioned to be more challenging as the number of base stations (BSs) per unit area, and the number of connections has been dramatically rising.

To improve the quality of experience (QoE) of the user in mobile networks, machine learning-based algorithms can be applied to find the optimal HO solution [3,4]. Some machine learning (ML) techniques used in mobile network handover are reinforcement learning [6,7], supervised learning [8–10], and unsupervised learning [11]. The main application approaches of this topic are target base station selection, handover performance prediction, and handover parameter optimization.

We have studied the possibility of using ML to learn the HO failures conditions based on real user equipment (UE) measurements while considering the radio conditions. To evaluate this, we developed a predictive classifier, which takes UE measurements and determines the conditions to HO failures. The concept was evaluated using test dataset of real measurements in a challenging industrial 4G network setup.

2 Methodology

The methodology of this work is oriented to satisfy the requirements of a Machine Learning process that starts with the data collection that includes the description of the variables measured in the populated city, data preprocessing, and creation of new variables of interest. Next, a statistical analysis of the constructed dataset will be made to define the behavior of the data. Finally, a Machine Learning process is applied to start with creating a training set and a test set, then applying a Machine Learning method and ending with evaluating the models created. For this case study, a classification method using Decision Trees and KNN techniques and a prediction method using linear regression were applied.

2.1 Data Collection and Preprocessing

The data were collected using cellular applications that allow measuring certain radio frequency variables of the cellular network. To start with the data collection, certain sectors of the city of Quito, Ecuador were chosen to cover many

cells, to ensure that handovers are executed, which will be called the handover zone. In addition, in these areas, the base stations that operate for the operation of the cellular network were identified through the use of the CellMapper web map tool. The location of the base stations was also visually verified in order to define the measurement routes using Google Maps.

Using the cellular application "Net Monitor Lite", radio frequency measurements were collected from the cellular network in the defined routes within the handover zones. The parameters measured by the application were:report, date, hour, network operator name, the strongest power from neighboring base stations (RSSI_STRONGEST), cellular technology, Mobile Country Code (MCC), Location Area Code (LAC_TAC), node identifier (NODE_ID), cell ID (CID), Received Signal Strength Indication (RSSI), Reference Signal Received Quality (RSRQ), Reference Signal Signal-to-Noise Ratio (RSSNR), accuracy, and latitude (LAT) and longitude (LONG) of the user equipment. The parameters provided by the application, we proceeded to select those related to the handover process, such as:

RSSI_STRONGEST: highest neighbor power.

NODE_ID: specifies the node's identifier.

CID: is a unique numeric identifier used to identify a specific cell in the network.

RSSI (Received Signal Strength Indication): a measure of the signal strength received by a receiver.

RSRQ (Reference Signal Received Quality): measure to evaluate the quality of the reference signal received by user equipment in relation to noise and interference.

RSSNR (Reference Signal Signal-to-Noise Ratio): reliability measure of the reference signal in an LTE mobile network, showing the Signal-to-Noise Ratio of the Reference Signal.

In addition, it is necessary to create the variables *hand_over* and ¨handover¨to use them in the Machine Learning models.

hand_over: It is a numeric variable with values of 0 and 1 that allows defining if there was a handover or not. This variable was determined considering that as the user equipment moves along the route, it makes a handover process when it changes from one base station or cell to another. Thus, if the value of the *node_id* variable is equal to the value of the next cell, then a logical value "0" will be assigned, which indicates that no cell change was made and therefore no handover occurred. And if the condition is not met, the logical value "1" will be assigned, which will represent the existence of a cell change, and therefore the existence of handover.

handover: This is a categorical variable that indicates whether the handover was successful or unsuccessful. In this connection, the handover process will be successful when it connects to the base station or failed when it tries to connect

and fails to establish the connection. Therefore, an additional attribute called *handover* is incremented, which is identified with the number "0" when the handover is failed or "1" when the handover is successful.

Other variables were also created for the models such as azimuth, which indicates the direction of movement of the mobile device by means of an angle, mobile speed and distance of the mobile from the serving base station.

2.2 Statistical Analysis of RF Parameters in the HO Process

Measured data were taken on the routes shown in Fig. 1 which is a measurement area with HO faults, where the data measurements were taken on the blue route. It shows the starting and ending points, where the red circles indicate the base station locations.

Fig. 1. Tracking route of the measurement areas for statistical analysis; (*a*) Route 1 (Quitumbe), (*b*) Route 2 (San Bartolo) and (*c*) Route 3 (La Floresta).

The data collected on route 1 by test equipment are 37383 samples, of which 2256 are in the handover zone and 1221 are considered successful handovers, with a percentage of 54.12%, and 1035 handover failures, with a percentage of 45.88%.

The measured data presented in route 2 are KPIs (key performance indicators) with 15503 samples: 1220 samples in the handover zone of which 637 are considered successful handover with a percentage of 52.21% and 583 samples for HO failures with a percentage of 47.79%.

4G KPI measurements are performed across in route 3 with 20,000 samples, where, 1516 samples are in the handover zone of which 646 are considered as successful handover with a percentage of 42.61% and 870 samples correspond to HO failures with a percentage of 57.39%.

The KPIs are analyzed based on statistical models to evaluate the performance of successful HO and HO failures through the use of statistical descriptors, correlation matrix, histograms and box plots.

This statistical analysis also provides insight into the behavior of the data before passing it to the Machine Learning model.

2.3 Machine Learning Methods

Classification Models. The analysis of RF parameters is carried out to make a classification of the handover stage (HO successful or HO failed) in LTE cellular networks using classification techniques such as decision tree and knn. The parameters to be taken into account are RSSI, RSSI_strongest, RSRQ, azimuth, mobile speed and distance of the mobile from the serving base station. The measurements were collected in a populated area of Quito, Ecuador, as shown in Fig. 2. The samples were collected in routes 1 (19942), 2 (75356) and 3 (25234) respectively, of which 1518, 16999 and 1711 samples correspond to the handover zone stage in routes 1, 2 and 3 respectively. The usual method is to divide the data set into a training set (80%) and a test set (20%).

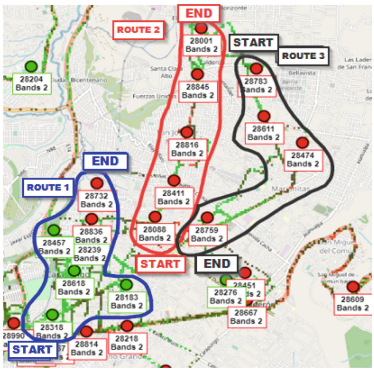

Fig. 2. Tracking area for HO classification; (*a*) Route 1 (Carapungo), (*b*) Route 2 (San José de Morán-San Juan de Calderón) and (*c*) Route 3 (San Juan de Calderón-Marianas)

Prediction by Linear Regression. This part focused on the HO failures predictions along with the methods of linear regression. Thus, the tested area mostly coverage with the 4G networks. Figure 3 displays the experimental tested (measurement area), where the data measurements were taken on the red route. Outdoor measurements were collected in San Juan neighborhood, which is in the historic urban area in Quito City. Samples are captured and gathered from two routes set in the tested.

A total of 66500 samples were collected in route 1 and 84500 samples in route 2 respectively. The dataset is used to build a model that will allow performing

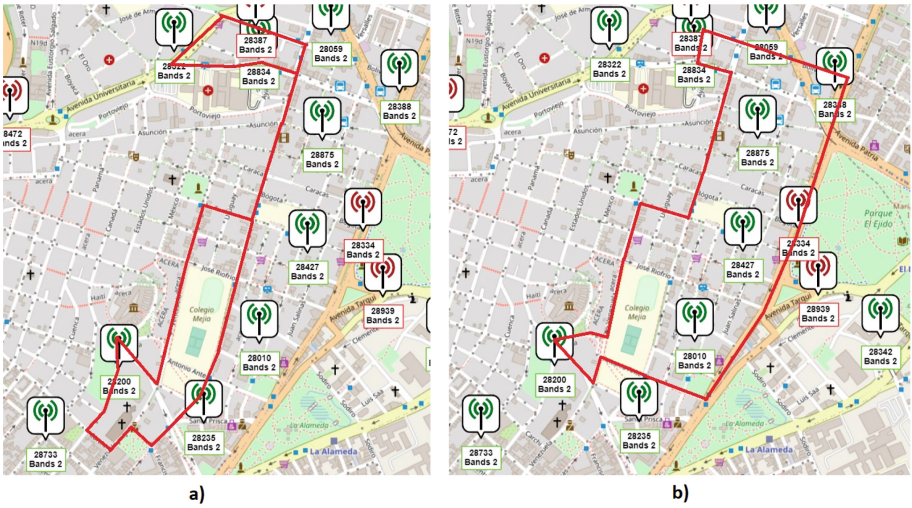

Fig. 3. Route map of the outdoor experiment for the HO failures prediction: (a) Route 1 (San Juan 1), (b) Route 2 (San Juan 2)

the regression task. The proposal is based on a supervised approach that trains for HO failures prediction. One subset of 20% is used as the test set, and the rest for training the model. Since RSSI_STRONGEST and RSSI are provided directly as inputs of the model; the output is the estimation of HO failures (*handover*). The actual parameters were decided in order to maximize the validation set results and the output of the model is of numeric type where "0" is HO failures. In this paper, the relationship between the independent variables RSSI_STRONGEST, RSSI and RSRQ and the dependent variable *handover* will be modeled to predict future values of a successful or failed handover. Through this model, the coefficients of a linear equation that will satisfy the relationship between the mentioned variables will be obtained.

3 Results

3.1 Statistical Analysis of Handover Parameters in Cellular Networks Based on Field Measurements

The results of statistical analysis of handover parameters indicate that 3 route's average RSSI differences vary between 8.7, 11.74 and 3.39 dB at HO successful and HO failures; route's average RSSI_STRONGEST differences vary between 3.36, 8.12 and 0.18 dB at HO successful and HO failures; route's average RSRQ differences vary between 2.17, 1.31 and 1.58 dB at HO successful and HO failures; and, route's average RSSNR differences vary between 0.26, 0.18 and 0.16 at HO successful and HO failures. According to the 3gpp recommendation [13,14], it is observed that the RSSI status corresponds to a very weak connection as does the RSSI_STRONGEST which has a mean value of -102.62 dBm and a standard

deviation of 11.26 dBm. When comparing the values with those stipulated in the 3gpp standard, it is found that the RSRQ parameter is in a good range. In addition, the RSSNR has a mean value, which is considered a regular level of this parameter.

Correlation Matrix. For the RSSI, RSRQ, RSSI_STRONGEST and RSSNR correlation matrix in the HO zone, where HO failures and successful HO, is considered. The results of KPIs correlation matrix indicate that in all the tracking routes achieve the highest correlation coefficient of 0.6988, 0.8120 and 0.6864 between RSSI and RSSI_STRONGEST in the three routes respectively.

Boxplots. The box plot allows you to graphically visualize the variability, as well as the shape of the symmetry of the data of a certain quantitative variable and to detect atypical values.

Figure 4 shows the RSRQ and RSSI at successful HO and HO failures points for all tracking routes. The results indicate that each route's average RSRQ difference is approximately 2 dB at successful HO and HO failures points. The average RSSI levels vary between −84 and −100 dBm and between −88 and −107 dBm at HO failures and successful HO points, respectively, for all routes.

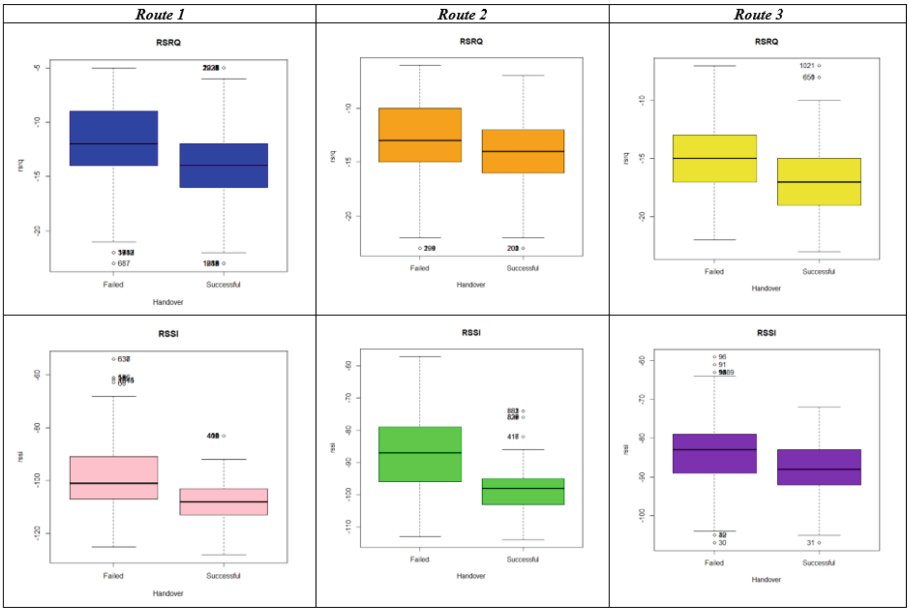

Fig. 4. Boxplot for RSRQ and RSSI.

3.2 Analysis of Handover in LTE Cellular Networks Using Machine Learning

Classification Models. The decision tree to handover classification is shown in Fig. 5. A decision tree model is trained with the labeled samples.

In this case, the first comparison parameter is the speed of the UE, given that the average speed of the route is 51 km/h, it is observed that if that speed is exceeded, there is a high probability that the handover will fail. Furthermore, if simultaneously the RSSI_STRONGEST is greater than −115 dBm increases the probability of handover failure. Of all the data, 95% of them result as "successful".

The results of investigated decision tree obtained from routes of urban area are summarized in Table 1.

To evaluate the model determined, the confusion matrix shown in Table 2 was obtained. When analyzing the confusion matrix, it is observed that out of a total of 284 data used for the test in the "successful" category, 273 data are correct, on the contrary out of 6 data that were used in the "failed" category, 5 have been correct. Then, in the evaluation metrics, an average value of 73.2% accuracy is observed in Table 3, and a value of 81.3% that will be used later for a comparison between models.

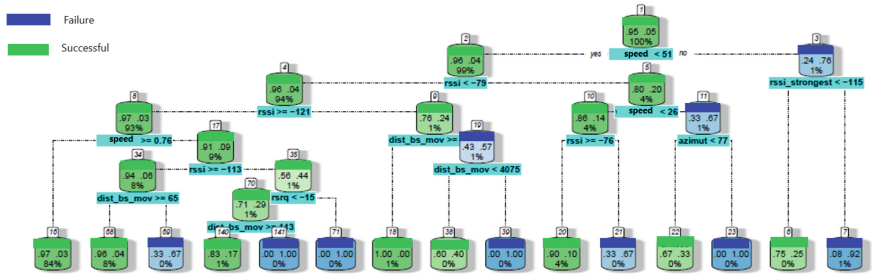

Fig. 5. Decision Tree to HO classification

Table 1. Summary Decision Tree

Category (Handover)	Distance eNB-UE	RSSI (dBm)	RSSI_Strong (dBm)	RSRQ (dB)	Azimuth (degrees)	Speed (km/h)
Successful	<113 m	> −79	< − 121	<=−15	<76.83	<0.26
Failed	>4075 m	<-113	> − 121	> − 15	>=76.83	>51

Table 2. Confusion Matrix

Test		
	Successful	Failed
Successful	273	1
Failed	11	5

Table 3. Collect Metric Decision Tree

Metrics			
Metric	Estimator	Mean	Std_err
accuracy	binary	0.732	0.0189
roc_auc	binary	0.813	0.0196

A Basic Prediction Approach for the HO Failures. The proposed model uses linear regression to predict HO failures. The model generates an expression that relates the two input variables RSSI and RSSI_STRONGEST to obtain the output that corresponds to the prediction of successful (1) or failed (0) handover.

According to the result of the model obtained, the expression that allows to determine if the handover is successful with a "1" or if it is unsuccessful with a "0" is represented by the Eq. (1).

$$hand_over = -0.00027r_s - 0.0025r - 0.2560 \tag{1}$$

where r is the RSSI variable and r_s is the RSSI_STRONGEST variable. Finally, to evaluate the prediction model, the root-mean-square error (RMSE) was calculated to determine its performance. The RMSE is 0.07709241, considered acceptable.

This study presented the analysis of the handover. However, several limitations are ignored. This study included the most relevant parameters. Several additional parameters, such as data rate and data traffic, can be considered. Thus, the scope can be further extended and include data measurements of a Mobile Network Operator infrastructure.

Conclusions

This study provided an analysis of handover using statistics and machine learning. The data measurements were conducted in Quito, Ecuador, with 4G technology infrastructure. Furthermore, when evaluating the statistical analysis of systems parameters, as it brings important information on the dependence between the HO failures and statistical parameters. Following, this paper presented the procedure to achieve HO failures classification through machine learning techniques by decision tree. Finally, this study proposed a linear regression based HO estimator which predicts the HO failure for any given combination of radio

frequency parameters. The proposed HO failure estimator is modeled, having as inputs RSSI_STRONGEST and RSSI. In addition, a limitation not considered in this study and can be a point to possible future work. This work benefits the mobile network operators to evaluate their HO network performance in a particular tested area.

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The Development of an Architecture Using Traditional and Modern Recursive Neural Networks and Natural Language Processing to Increase the Accuracy of Response on Client Doubts Related to Public Services

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Abstract. In modern days customer service has become fundamental part in companies. The offer of customer services has been applied to many international companies, unfortunately domestic companies in Latin America lack the implementation of these services especially those companies that offer basic services. Most of these companies offer hotlines, and websites but these options may seem like time consuming and frustrating for customers to interact to. For this reason, we propose an innovative architecture to implement Spanish chatbots in companies that offer basic services. Modern international companies already offer constructed chatbots, but unfortunately these chatbots tend to be constructed with English language. This architecture aims to increase the accuracy in which it responds to a client's doubts, saving them time and avoiding causing them frustration. In the case of this research, we have used a Latin American electric company that offers basic services, in this case there is no such dataset constructed in Spanish for these companies and for this reason we constructed our own dataset using the company's website information. We compared the results of the model based on a rnn transformer architecture and seq2seq. As a result of this research, the proposed method achieves an accuracy of 91.57% and a loss of 1.76% with the transformer model. As a future research we suggest the implementation of special characters such as emojis and the increase of dataset to analyze the behavior and accuracy of these models.

Keywords: Machine Learning · Recurrent Neural Network · Natural Language Processing · Sequence to Sequence · Transformer · Chatbot · Human Resources · Electric Company

1 Introduction

This section is organized 2 Subsects. 1) fundamentals of chatbots, 2) fundamentals of machine learning. In a research done before [9] we applied a similar

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architecture in which we applied the same procedure to improve the accuracy of certain model. For this reason, we have applied a similar solution.

1. Fundamentals of chatbots: [5] humans look forward to artificial intelligence (IA) advancing in technology and many scientists and programmers look forward to creating human like machines. To accomplish this task a machine most first learn to interpret images, language, speech, and text. Hence the first chatbot was created in 1966 named ELIZA the main objective of this chat bot was to simulate a psychotherapist, unfortunately it wasn't a success. These types of chatbot have evolved with time and the main objective of these chatbots are to initiate a conversation with a real person in a manner in which the person doesn't recognize it's talking to a machine.
2. Fundamentals of machine learning: [8,12] as its name suggests machine learning is based on building machines; these machines are mostly trained to perform a certain task. The methods or manner in which the machines are created is by implementing ideas that have been around for some time. These methods are structured by implementing probabilistic models using a dataset that is preprocessed in a mathematical manner to obtain a mathematical result.

In Latin America companies should offer better customer services especial companies that offer basic services such as, electricity, and water. Our architecture is based on how we prepare the data before applying them to the RNN model, in our case there are few implementation of natural language preprocessing (NLP) for Spanish language and we wish to encourage the growth of NLP for other languages apart from English. Natural Language Processing (NLP) has been primarily focused on the English language, leading to a lack of NLP tools and resources in Spanish. This has resulted in limited progress in NLP research and applications for Spanish-speaking communities. To bridge this gap, the objective of this article is to propose models that enhance NLP in Spanish and promote language equality in the field of NLP. The proposed models will pave the way for further research and development in NLP for Spanish, enabling equal development with the constantly evolving English language in NLP technologies. Our architecture incorporates the following steps.

1. Selection of data set or preparation of dataset.
2. Natural Language preprocessing
3. Vocabulary/Dictionary Generation.
4. Training & modeling.
5. Evaluation of Experiments and Results.
6. Interpretation of Results.

This research is structured as follows: II. Related work, III. Proposed method, IV. Design and experiments, V. Results, and discussions, and VI. Conclusions. The highlights of this research are summarized below:

- The development of natural language preprocessing for Spanish language
- A data science-based architecture for preparation, modeling, evaluation and interpretation of results.

- A comparison of accuracy of our architecture applied to two different models of RNN
- Encourage the increase of natural language preprocessing for other language apart from English.
- Incorporate a successful chatbot to answer clients doubt on companies that offer basic services

2 Related Work

This sections will present researches that have implemented similar techniques as this research. First, we will briefly describe research that have used machine learning (RNN) and the level of success that these have had in their experiments.

In [2] the authors proposed the implementation of RNN in chatbots to help people who suffer with depression. To implement this research, they used a data set that is made from twitter tweets. Their canny chatbot takes clients input and answers in a manner in which it intents to lower down their pressure level. The architecture that they used is long short-term memory (LTSM). Their characteristics of their model were; 50 epochs with a learning rate of 0.01. in the end they obtained a 70% of exactness in reducing the clients sadness.

In their work [6], the authors employed innovative techniques to develop an application for text summarization. They utilized a state-of-the-art language model, the transformer, which is known for its pre-trained language capabilities, to generate Arabic text summaries. The authors created their dataset, consisting of 84,764 high-quality text summary pairs. Their research revealed that AraT5 performed exceptionally well, as evaluated by ROUGE metrics, and highlighted that both AraT5 and AraGPT2 excelled in summarizing out-of-domain data.

Another research similar to the one mentioned before [7] uses tweets from twitter and proposes a text classification based on tweets due to the fact that these tweets seem to lack form of expression and can sometimes result as ambiguous. They combined different model to this research such as: CNN, RNN, BiLSTM. As a result of their research, they discovered that the combination of Bidirectional Encoder Representations from Transformers (BERT) and CNN, RNN, and BiLSTM performed well giving promising results using the quality measures: accuracy, recall, precision.

In [11], the authors introduce a politeness generator based on conversations. They leverage two datasets, one containing politeness-annotated dialogues and another consisting of generative data. Their research shows that applying an RNN-based model (seq2seq) with reinforcement learning enhances the accuracy of generating polite responses without relying on predefined keywords. This approach aims to enhance customer satisfaction by improving the politeness of service interactions. The study highlights a shift towards using traditional and modern RNN techniques in chatbots for enhancing client satisfaction.

In [3], the authors use machine learning to improve product recommendations. They propose an Enhanced Elman Spike Neural Network for sentiment analysis in online product recommendations, utilizing collaborative filtering and

product similarity. Their dataset, derived from Amazon reviews, undergoes preprocessing to filter out specific details. The Elman Spike Neural Network classifies recommendations into categories like excellent, good, very good, bad, or very bad. The proposed method outperformed existing methods, achieving significantly higher precision and F-Score results.

In a study from Taiwan [4], customer loyalty and satisfaction were assessed concerning service chatbots. The research, based on feedback from 219 users, revealed that the quality of chatbot interactions significantly influences user satisfaction. Furthermore, the study showed that core AI chatbot service quality and user satisfaction are key factors affecting user loyalty. As a result, the authors recommend the development of a more human-like chatbot with improved conversational quality and e-service quality comprehension.

3 Proposed Method

Research often involves proposing new methods, which can be distributed into different phases. Each phase presents its own unique challenges with varying levels of difficulty. This article proposes a specific method, which is designed to address the challenges associated with developing a chatbot for Spanish-speaking users of an electric service company. In the subsequent sections of this article, we will outline these challenges in detail and describe the strategies we employed to overcome them. Through this investigation, we aim to contribute to the development of effective chatbots that can enhance the quality of customer service in Spanish-speaking communities.

Developing a chatbot for Spanish-speaking users of an electric service company requires overcoming a range of challenges. These challenges can range from technical limitations to linguistic differences, and can significantly impact the success of the chatbot. In this article, we propose a method that addresses these challenges in a structured and systematic manner. By breaking down the process into different phases, we are able to identify and address the challenges in a more targeted way. Our approach is designed to be adaptable and scalable, making it suitable for a variety of different chatbot development projects. Ultimately, we hope that our research will contribute to the advancement of chatbot technology and improve customer experiences in Spanish-speaking communities (Fig. 1).

The phases are as follow:

1. Recollection of Data.
2. Natural Language Preprocessing.
3. Vocabulary/Dictionary Generation.
4. Training & modeling.
5. Evaluation of Experiments and Results.
6. Interpretation of Results.

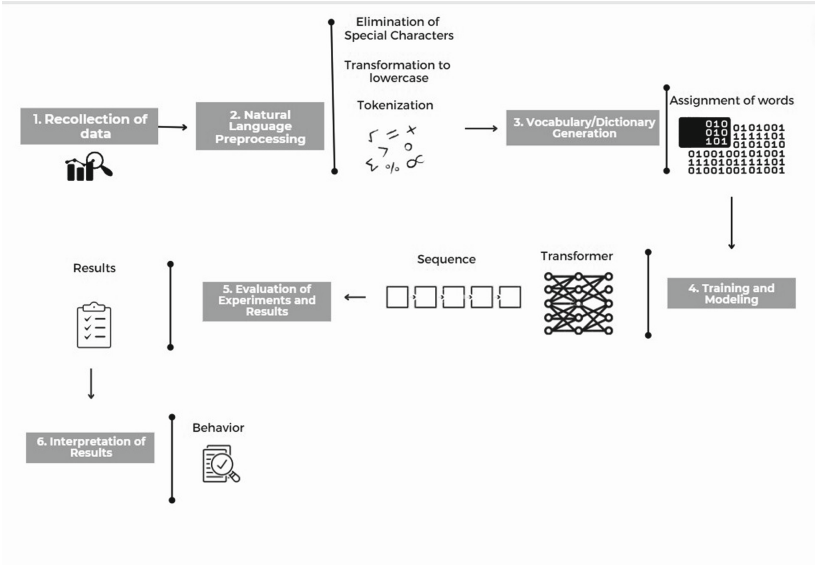

Fig. 1. Proposed architecture for the development of a chatbot

3.1 Recollection of Data

One of the first challenges presented in this research is the creation of our own dataset. This is due to two proposed objectives, this first objective is to obtain a dataset that is composed of data in Spanish. The second objective is to have information focused on an industry that offers electric public services. The combination of these objectives being the fundamental pillar for the creation of this dataset, where it will allow to combat the problem of not having a virtual agent that supports this sector.

The structure that we handled in this dataset was the creation of two columns from which the first column has all the possible questions and the second column had answers that were obtained from the website. This section is focused on the virtual agent that can implement this training.

3.2 Natural Language Preprocessing

Once the dataset has been structured, data processing is conducted. This procedure will allow the improvement of precision within the machine learning techniques used in virtual assistants, it will also allow us to have a text with greater ease of processing.

Filters were used for this procedure, the first filter is responsible for changing special characters, such as: *?/”’ among others. The second filter applied in this subsection is the process of vowels that have accent mark, being a symbol that represents punctuation of some words in Spanish, in this step the change of the letter ñ was added, the same one that is used in the Spanish language.

3.3 Vocabulary/Dictionary Generation

In data science, machine learning models can be trained using a vocabulary or dictionary, which assigns a number to each word to improve the natural language processing. In order to create such a vocabulary, a JSON file can be utilized. This file allows for a list of items and their corresponding values, where the attribute represents the word and the value is the assigned number. By using this technique, machine learning models can be trained to more effectively process and analyze natural language data.

Creating a vocabulary or dictionary is an essential step in natural language processing for machine learning models. The use of a JSON file allows for efficient storage and retrieval of the assigned values for each word in the vocabulary. By incorporating this technique, the machine learning models can better analyze and understand natural language data, enabling the development of more accurate and effective models in data science.

3.4 Training and Modeling

In this investigation, two models based on RNN were proposed, one being sequence to sequence and the other the transformer. The first is a sequence-to-sequence neural network (Seq2Seq) is a type of deep learning model used for machine translation tasks, speech-to-text transcription, text generation, and many other applications involving input and output sequences. This model consists of two main parts: an encoder and a decoder. They are useful because they allow you to model tasks that involve sequences of variable lengths and different relationships between inputs and outputs. Furthermore, these models are highly scalable and can be trained in parallel on GPUs, allowing for fast and efficient training (Fig. 2).

The second model is a transformer neural network, the same one that uses a structure called multi-headed attention to allow the network to pay attention to different parts of the input stream at the same time. This allows the network to capture more complex relationships between inputs and outputs, which translates to higher accuracy in complex tasks. This allows the need for a hidden state structure in traditional RNN to be eliminated, allowing the network to process longer sequences with greater speed. This also makes it easier to train and regularize the network, which leads to better performance on complex tasks (Fig. 3).

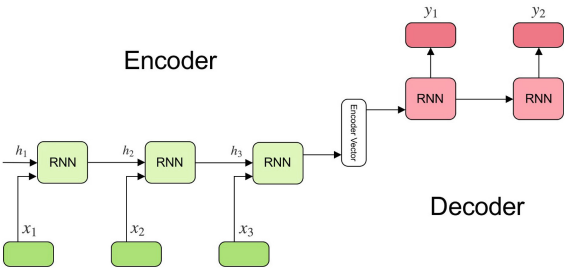

Fig. 2. Structure of a Model Seq2Seq [1]

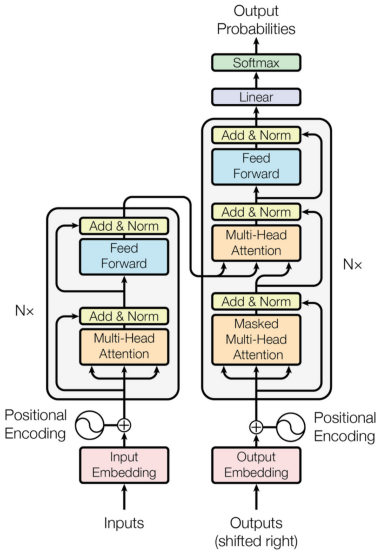

Fig. 3. Structure of a Model Transformer [10]

For the training process of this model, we used the following parameters "Table 1".

Table 1. Table of Results

Parameter	Description	seq2seq	transformer
BATCH_SIZE	Data batch size for model training	2	2
MAX_SEQUENCE	Maximum sequence length for data processing	100	100
EPOCH	Full step of training a model on all data	50	50
VALIDATION_SPLIT	Percentage of validation data in training	0.2	0.2

3.5 Evaluation of Experiments and Results

To evaluate our models, the use of two quality measures are used, these being the following:

1. Accuracy: Defined by the number of predictions made correctly divided by the total number of predictions made. Referring to how close it is to a true value result.

$$Accuracy = \frac{VP + VN}{VP + VN + FP + FN} \tag{1}$$

   - TP: True Positive
   - TN: True Negative
   - FP: False Positive
   - FN: False Negative

2. Loss: It measures the difference between the model predictions and the actual values and is used to measure model error.

The evaluation of our models with these quality measures provide us with the results presented in "Table 2".

Table 2. Table of Results

Model	Accuracy	Loss
Sequence two sequence	87.72%	0.0292
Transformer	**91.57%**	**0.0176**
Model [2]	84.76%	N/A
Model [6]	70.00%	N/A

3.6 Interpretation of Results

The use of neural networks in data processing has allowed greater precision in solving complex problems. In this case, two types of neural networks were compared: the Sequence to Sequence neural network and the Transformer neural network. The results obtained show that the Transformer neural network has obtained better results in terms of model quality. The Sequence to Sequence neural network had an accuracy rate of 87.72% and a loss rate of 0.0292, while the Transformer neural network had an accuracy rate of 91.57% and a loss rate of 0.0176.

These results indicate that the Transformer neural network is a more effective option in data processing and can provide more accurate solutions compared to the Sequence to Sequence neural network. The Transformer neural network has proven to be a valuable tool in data processing and is likely to continue to be used in the future. In summary, these results suggest that the Transformer neural network is an effective tool for solving complex data processing problems and providing accurate and reliable solutions.

4 Conclusions

The results obtained in the sequence two sequence neural network and the transformer neural network demonstrate the effectiveness of artificial intelligence technology in natural language processing. The transformer neural network, with the proposed architecture, achieved better performance in the Accuracy and Loss metrics compared to the sequence two sequence neural network. This shows that the implementation of the transformer architecture in natural language processing has improved the quality of the model and provides us with a solution to face the problem of virtual assistants for electric companies that speak Spanish.

The success of the transformer neural network gives us the opportunity to continue investigating the interpretation of the Spanish language with artificial intelligence. For future work, we can consider increasing the robustness of data processing, such as emoticon interpretation and increasing the dataset to have a more robust virtual assistant. In addition, this could be a support for companies that want to evolve and implement artificial intelligence technology in their digital platforms.

Artificial intelligence technology and natural language processing have great potential in improving businesses and their interaction with customers. By having a more accurate and efficient model, we are able to provide better customer service and support, which is essential to the success of any business. The implementation of the transformer neural network and its success on quality metrics is an important step in the right direction to achieve these goals.

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A Systematic Mapping Study on the Use and Development of Research Software

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Abstract. Modern research depends on software, and it is developed specifically for and during research. Moreover, a growing number of researchers develop and use software to conduct or support their research. However, an overall understanding of research software is still needed. Our goal is to characterize the publication landscape on research software use and development that have been used in the context of software outlining research contributions and contemporary gaps for future research. We conducted a systematic mapping study and identified 20 studies published in the last 15 years. We found several types of contributions, in which there is an emphasis on analysis and some trends in the type of research evaluation, and the main type of empirical evaluation is a survey. Our results suggest that there are opportunities for solution proposals to address gaps concerning factors that influence research software success in an academic context, providing guidelines, checklists, and models.

Keywords: Experimental Software Engineering · Systematic Mapping Study · Empirical Research · Research Software · Use and Development

1 Introduction

Software is clearly essential in research, and much of this software is developed specifically for and during research. Many researchers in scientific, engineering, business, and humanities domains increasingly develop and/or use software to conduct or support their research [1]. This software is referred to as research software and consists of tools, libraries, and end-user software or applications [2]. Moreover, in the last years, relevant studies have been discussed and increased to understand how researchers develop and use research software [1–4]. Examples of research software developed or used by researchers include interactive development environments for research (e.g., Jupyter), workflow managers (e.g., Snakemake), frameworks to generate documentation (e.g., Overleaf), reference management software (e.g., Mendeley, Zotero, JabRef), and mathematical or statistical libraries and tools (e.g., Atlas.ti, R, scikit-learn) [3,5].

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In the last decade, research software used and developed in academia has been of interest to study, and some studies presented that academic researchers are unable to work without it. A comprehensive survey reports that more than 90% of respondents, 92% of UK academics and 95% of US academics, said they use research software. More than 60% of the respondents said that they were unable to work without software [6–8].

Research software is used and developed daily by researchers in research centers, national laboratories, industries, universities, communities, and practitioners [9]. Moreover, research software is most often used and developed by researchers themselves, often within academia, by faculty, staff, postdocs, and students [10,11]. Software engineering researchers have developed several practices that result in software overall with higher quality [12,13]. However, although researchers invest a large fraction of their time, more than 40%, in building software, they often do not take full advantage of the advancements in software engineering (SE). This lack of SE practices can be attributed partially to limited knowledge of the benefits of these practices [13]. Moreover, there are several factors that result the software development in a not efficient or sustainable way. Best practices that provide academic researchers methods for performing development, ease maintainability and that encourage sustainability and reproducibility are not widely used [10,14,15].

Therefore, due to the importance of research software, our work contributes by reporting a systematic mapping study with the objective of synthesizing existing works related to the use and development of research software to provide an overview of relevant studies published in the last 15 years and to understand the main contributions in the research software area. We aim to characterize contributions, research types, and empirical evaluations. Our search method is driven by broad research questions and uses a hybrid search strategy [16–18], combining database search with backward and forward snowballing.

The structure of this paper is organized as follows: in Sect. 2, we delineate the related works. In Sect. 3, we explain our systematic mapping protocol, including the goal and research questions, search strategy, study selection, and data extraction. In Sect. 4, we present the results. In Sect. 5, we engage in a comprehensive discussion on the findings derived from the results. In Sect. 6 we present the threats to validity. Finally, in Sect. 7, we present the limitations and conclusions of our study.

2 Related Works

This section describes secondary studies (systematic mapping studies or systematic literature reviews) related to the application of software engineering practices for scientific software or research software. We identified the most recent papers that present secondary studies:

Farhoodi et al. [19] presented a systematic mapping study and a bibliometric study. The authors describe software engineering techniques and activities that are being used in the development of scientific software. As a result, the authors

suggest that many software engineering techniques and activities are being used in the development of scientific software. However, there is still a need for further exploration of the usefulness of specific software engineering techniques.

Heaton and Carver [12] conducted a systematic literature review examining claims about how scientists develop software. The study contains 33 different claims about 12 software engineering practices. As a result, the majority of the claims indicated that software engineering practices are useful for scientific software development.

Elvira et al. [13] performed a systematic mapping study on the use of software engineering practices for scientific application development and their impact on software quality. The authors describe a catalog of SE practices used in scientific software development and discuss the quality attributes of interest to the practices. The results indicate that scientific software developers are focusing on practices that improve implementation productivity and that maintainability is important.

3 Systematic Mapping Protocol

Systematic mapping studies are designed to give an overview of a research area through classification and counting contributions in relation to the categories of that classification [20]. The mapping studies are a potentially useful starting point for researchers and their results have several benefits [21]. It can help to identify gaps in the set of primary studies, where new or better primary studies are required, and can indicate directions for new research [19]. This section presents our protocol for the systematic mapping study based on the guidelines provided by Petersen *et al.* [20].

3.1 Research Goals and Questions

Our main research goal is to characterize the contributions that have been published related to the use and development of research software. Our Research Questions (RQ) are:

RQ1. What Types of Contributions Have Been Emerged to Support the Research Software Use and Development? We aim to provide an overview of contributions (e.g., approach (methods, methodologies, processes), model, framework, checklist, guideline) on the research software and do not restrict to studies in only one context of research software development.

RQ2. Which Types of Research Have Been Conducted Regarding Research Software? We aim to use a commonly scheme to classify the types of research identified [22].

RQ3. Which Types of Empirical Evaluation Have Been Performed in Research Regarding Research Software? We aim to identify the types of empirical evaluation that have been performed in research papers [23].

RQ4. Which Topics Have Been Addressed in Research Regarding Research Software? We aim to identify the specific topics that were the focus of the contributions and the practices to understand their purpose.

3.2 Search Strategy

A recent study comparing different search strategies to perform Systematic Literature Reviews (SLRs) in Software Engineering found that using a hybrid strategy combining a database search on Scopus with parallel backward and forward snowballing tends to present an appropriate balance between result quality and review effort [17]. Moreover, another study comparing and evaluating hybrid search strategies found that the hybrid search strategy is a successful combination of database search and snowballing for the identification of primary studies when performing systematic literature studies [18]. Thus, we adopted the hybrid search strategy, involving applying a search string on the Scopus database, filtering the results using our defined inclusion and exclusion criteria, and performing parallel backward and forward snowballing iterations on the remaining studies [16,17]. Studies have successfully applied this search strategy [24–26].

We designed our search string to conduct the database search on Scopus using the PICO (Population, Intervention, Comparison, Outcome) criteria [27] as follows: Population: research software (and scientific software for a broad view); Intervention: software methodology, tool, technology, framework, model, or procedure; Comparison: there was no specific comparison; Outcome: there was no measurable outcome. Thus, our search string, to be applied on titles, abstracts, and keywords was: *"("software engineering" OR "development" OR "use") AND ("research software" OR "scientific software")"*.

3.3 Study Selection

The Inclusion Criteria (IC) and Exclusion Criteria (EC) to filter the studies are presented in Table 1. The search in the Scopus database returned a total of studies 3,771. First, we applied the selection criteria (SC) to the title and abstract, filtering papers and obtaining relevant studies, formed by studies. After that, we applied the SC to the full text, to obtain our seed set with relevant studies and after a strategy search obtained 20 studies.

Table 1. Inclusion and Exclusion Criteria

Criteria	Description
IC01	Describe contribution related to the study published
IC02	Published between 2008 and 2023
EC03	Papers that do not meet the inclusion criteria
EC04	Not written in English
EC05	Not published in a peer-reviewed conference, journal, or workshop area
EC06	Papers that are only available in abstracts/posters, presentations and are short paper of a full version
EC07	Grey literature, theses, and papers that were not peer reviewed

3.4 Data Extraction

The information extracted from each of the selected papers and the classification schemes describing the different categories to answer the research questions are presented in Table 2. The details of the sequence of the study selection process, the mechanisms used in each step of the process, and the dataset collected that support the findings of this study are available at Zenodo in the link https://doi.org/10.5281/zenodo.10050140

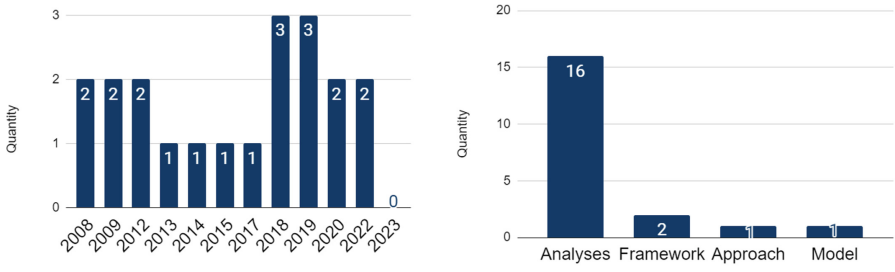
Table 2. Data extraction form

Information	Description
Study metadata	Title, authors, year of publication and short description
RQ1. Contribution	Classification of the contribution according: analyses, approach, framework, model, checklist
RQ2. Research type	Classification of research type according to these categories: evaluation research, proposal of solution, validation research, philosophical paper, opinion paper, or personal experience paper
RQ3. Empirical evaluation	Classification of the empirical strategy according to these categories: experiment, case study, survey
RQ4. Topics and practices	Topics of research and practices used to understand their purpose

4 Results

4.1 RQ1. What Are Types of Contributions Have Been Emerged to Support the Research Software Use and Development?

The selection process returned papers published between 2008 and 2023 as shown the Fig. 1 (a). It is possible to observe a concentration of research on the topic of research software in recent years. The identified contributions on the returned papers published are Analyses [1–4,7,15,28–37], Approach [38], Framework [39,40] and Model [10] as show the Fig. 1 (b).



(a) Distribution of research per year

(b) Distribution of research type

Fig. 1. Contributions to support the research software

4.2 RQ2. Which Type of Research Has Been Conducted Regarding Research Software?

Figure 2 presents the distribution of research types of the selected papers. We can observe that evaluation research [1–4,7,10,15,28–34,38] leads with 15 papers, followed by personal experience paper [36,37] with 2 papers. Philosophical [39], proposal of solution [40], and opinion paper [35] categories was only one paper. Note that papers that are widely explored to understand the use and development of software typically involve evaluation research.

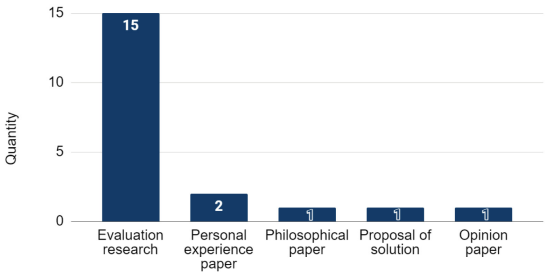


Fig. 2. Distribution of research type

4.3 RQ3. Which Types of Empirical Evaluation Have Been Performed in Research Regarding Research Software?

Figure 3 presents the distribution of empirical evaluations. We found 12 papers that conducted survey [1–4,7,28–34], while two case studies [10,38] evaluations and two interviews [15,40] were reported. Finally, 4 papers did not report any type of empirical evaluation [35–37,39].

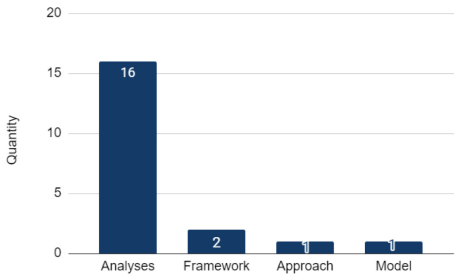


Fig. 3. Distribution of empirical evaluations

4.4 RQ4. Which Topics Have Been Addressed in Research Regarding Research Software?

The topics were organized in: (i) how researchers develop and use research software, characteristics of research software use and development, the training they have received in software development, and challenges in the research software development [1–4,7,28–38,40], (ii) a rank of importance of software engineering concepts [28], (iii) framework to organization [39] (iv) models to organizations [10], and (v) sustainable development [4,15].

5 Discussion

The concentration of publications on research software is over more than a decade. Despite the increase in publications in recent years, it is possible to note that greater scientific contributions are still needed. Several different research contributions have been proposed recently regarding research software. These contributions comprise analyses, approaches, frameworks, and models. It is evident that there are still relevant gaps to cover, for example, contributions related to checklists and guidelines to guide the development to provide better software. With respect to the type of research and empirical evaluation, we observed that there is still a limited amount of solution proposals, only one [40] in research type, and that 4 out of 20 (20%) papers [35–37,39] did not contain any type of empirical evaluation. This could be related to the fact that it is little discussed and improved in the academic context and which is still to acquire maturity and to move towards more rigorously assessed empirical evidence.

The main topic is addressed to how researchers use and develop research software. The importance of software engineering practices for delivering research software is clear in several papers. However, this work shows that this area needs further investigation and moreover to be addressed in an academic context. Another interesting fact is that only two papers investigate sustainable practices in research software development [4,15]. This topic of software sustainability is a growing field and we believe that this should be further investigated.

While these previous studies provide background and insight about research software development and use, practices and process, and their sustainability, a recent publication, after our systematic mapping was carried out, identify and understand the factors that determine successful research software, as well as investigate the factors of non-success and challenges involved in research software to become successful [11]. We strongly believe that these topics represent interesting research opportunities in future works.

6 Threats to Validity

Although we aimed to reduce the threats to the validity of our study methodology, some decisions may have affected the results of our mapping study. We present and discuss the threats to validity based on the presented in [23]:

Regarding *External Validity*, to generalization of our results, we define our protocol to enable reproducing our results. Moreover, the spreadsheets was used to control the study selection, extracted data from all the studies, and are available.

Regarding *Internal Validity*, we followed the guidelines proposed by Petersen et al. [20] and a hybrid search strategy that has been effective in identifying relevant studies [17].

Regarding *Construct Validity*, to the generalization of the study results, a threat is studies only about research software. To minimize it, we attempted to select studies related scientific research and research software.

Regarding *Conclusion Validity*, to the reliability, the mapping protocol was discussed with other researchers.

7 Conclusions

The overall goal of this paper was to present the results of a systematic mapping study on the use and development of research software. We applied a hybrid search strategy and our search strategy identifying a total of 20 studies. We extracted information related to contribution, type of research and empirical evaluation, and topics addressed in research. This work provides insights and although the number of relevant studies selected is small, in future research, we intend to expand the version of this work to a Systematic Literature Review. Hence, the main contributions of this research are: (i) mapping relevant knowledge about the current state of research software use and development; and (ii) helping to identify points that still require further investigation. Furthermore, modern research depends on software and understand the literature is vital for successful software.

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Software Systems, Architectures, Applications and Tools

Successful Case in the Development and Implementation of a Multi-company Inventory Management System Based on Communication Protocols Remote Procedure Calls (GRPC) and Server-Sent Events (SSE)

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Abstract. In today's complex business environment, inventory management across multiple retailers presents challenges. Traditionally, each company used its own inventory system, leading to communication issues and inefficiencies. Interoperability between systems was hindered by different technologies and protocols. To address these challenges, a multi-company inventory management system was developed, utilizing the gRPC and SSE communication protocols. gRPC offers high-performance communication through remote procedures, while SSE enables asynchronous event transmission. The system aims to enhance coordination and visibility, allowing companies to share real-time information for data-driven decision-making. Using the SCRUM methodology, customer needs were prioritized, delivering features such as user management, product tracking, order generation, and geolocation integration. The architecture comprised Data, Business, and Geolocation layers, ensuring data accuracy and efficiency. Comprehensive testing validated system functionality, including real-time inventory updates, dynamic route generation, and insightful reports. In conclusion, the system successfully improves multi-company inventory management, promoting efficient communication, synchronization, and data-driven decision-making. Rigorous testing ensures reliability and scalability, offering businesses a robust inventory management solution.

Keywords: Inventory Management System · gRPC · SSE · Management System · Dashboard · Business Intelligence

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1 Introduction

In today's business environment, inventory management has become an increasingly complex challenge, where companies operating with multiple retailers face additional difficulties in coordinating and optimizing their inventories effectively. Until recently, each company used to have its own inventory management system, which led to communication issues, lack of synchronization, and difficulties in sharing real-time information.

Furthermore, interoperability between different inventory management systems was a significant challenge, as each company could use different technologies, data formats, and communication protocols. This hindered the integration of systems and the transfer of accurate and timely information between them.

To address these challenges, the need for developing a multi-company inventory management system that would enable efficient and real-time communication between different systems became evident. In this context, communication protocols such as Remote Procedure Calls (gRPC) and Server-Sent Event (SSE) emerged as promising technological solutions.

Consequently, gRPC is a high-performance communication protocol that facilitates efficient and reliable communication between different systems, relying on remote procedures to enable calls and responses between various distributed applications [1]. On the other hand, SSE is a protocol that allows asynchronous event streaming from a server to a client through a persistent HTTP connection [2].

With this background, the implementation of a multi-company inventory management system was carried out with the objective of improving coordination, efficiency, and inventory visibility. This allows retail companies to share information quickly and accurately, enabling them to make data-driven decisions in real-time and on product distribution maps [1].

2 Related Works

In the field of inventory management systems and communication protocols, the state of the art has seen significant advancements in recent years. One notable trend is the shift towards cloud-based systems, which enable remote and real-time access to inventory information, facilitating collaboration across different geographic locations and improving operational efficiency. Cloud-based inventory management systems offer advantages such as scalability, data security, and the ability to integrate with other business solutions [3].

In this context, Rompecabezas, a Guatemala-based company specializing in educational products, experienced a resurgence in its sales due to events related to the COVID-19 pandemic. However, this growth highlighted issues in inventory management, which affected the supply chain and resulted in losses and a decrease in sales due to the lack of up-to-date controls and reliable data about their available stock [4].

Furthermore, in [7], a case study was presented involving a hospital operating room that assessed a Radio-Frequency Identification (RFID)-enabled traceability system for the management of consignment and high-value products requiring traceability. The

results indicate that the traceability system, coupled with the restructuring of replenishment processes, enhances traceability, improves financial controls, minimizes costs, enhances service levels, and reduces inventory fluctuations, thus substantiating the findings reported in [5, 6].

Regarding the algorithms used in inventory management, more advanced and sophisticated models have been developed, taking into account various factors such as demand, storage costs, and lead times, to make optimal replenishment decisions and maintain an adequate level of inventory. Some examples of these models include the Continuous Review model, the Periodic Review model, and the Order Point model. These algorithms allow for the optimization of the balance between inventory holding costs and the risk of stockouts [8].

On the other hand, the use of machine learning techniques has also gained relevance in inventory management as they can analyze large amounts of historical and real-time data, identify patterns and trends, and make more accurate predictions about future demand. This helps reduce inventory costs by avoiding overstock or understock situations and improves customer satisfaction by ensuring adequate availability of the most requested products [9]. For instance, in [9], a research study was conducted, examining in detail the application and benefits of neural networks in inventory management design.

Lastly, the focus on sustainability and the green supply chain has gained importance in inventory management, where companies are increasingly considering environmental and social aspects when making inventory-related decisions [10]. This involves optimizing transportation routes to reduce carbon emissions, selecting suppliers committed to sustainable practices, and reducing waste through strategies such as just-in-time and material recycling [11].

3 Methodology

In order to achieve an intelligent inventory system through constant inspection and feedback in development, thereby reducing project complexity, the SCRUM methodology has been adopted. In this way, the customer is placed at the center, and efforts are made to continuously and optimally meet their needs [12]. The first stage of the methodology corresponds to planning approach based on the delivery of functional software increments in short time periods [13]. To achieve this, the following requirements and functionalities were defined:

- User Login
- Registration of Company Information and Affiliated Subsidiaries
- Registration of Employees within a company with usernames and passwords
- Visualization of Company Information, Affiliated Subsidiaries, and their respective locations
- Registration and Management of Categories
- Registration and Management of Products
- Registration and Management of Taxes
- Order Generation
- Route Generation for Distribution based on active orders
- Creation of Descriptive Reports

These form the foundation of the system, which aims to cover basic needs and ensure smooth operation in a simple and optimal manner. To achieve this, the next stage is the implementation of a system architecture, as depicted in Fig. 1, which utilizes the communication protocols GRPC and SSE to enable efficient communication between different companies and the central server. System components were defined, such as GRPC services for inventory management and SSE events for real-time data updates.

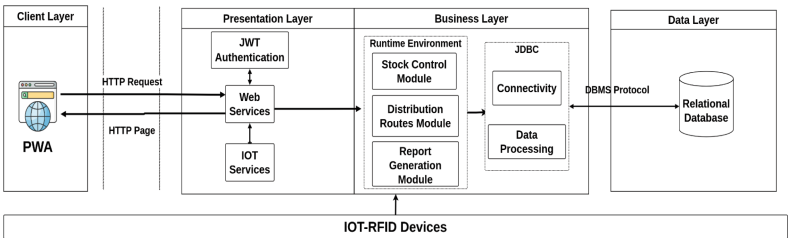

Fig. 1. Devices IOT.

This architecture was implemented with three layers, which are described below:

- **Data Layer:** In this layer, PostgreSQL is found, which is a relational database responsible for storing all data coming from the business layer and providing it when queried.
- **Business Layer:** A connection is established with the data layer and the object relational mapping (ORM) tool, GORM, is used to generate queries to the database. To facilitate communication, REST services have been developed using the GIN framework in the Go programming language. These services are responsible for receiving, processing, and transmitting information between the presentation layer and the data layer or IoT devices. Additionally, the gRPC framework is used to capture inventory data, providing a robust platform for defining and building highly efficient remote procedure call (RPC) services. To ensure real-time data transmission to the presentation layer, server-sent events (SSE) have been leveraged. SSE allows one-way, asynchronous updates from server to client over HTTP connections.
- **Geolocation:** Two APIs were used for geolocation purposes. The Maptiler API, an open-source solution, was used to display companies and sub-companies. For route generation, the Google Maps API was utilized.
- **Presentation Layer:** The system commences with an authentication window, serving as the gateway to the entire system. Access control is enforced through the implementation of a JWT guard. The JWT Guard validates the integrity of JSON Web Tokens (JWT) held by users, ensuring security and safeguarding sensitive data and functionalities, including user authentication and data management capabilities. It plays a pivotal role in allowing or denying access to specific routes or queries directed toward the Business Layer. Once a user is authenticated, they gain access to diverse menus and interfaces, enabling them to efficiently manage and execute various processes via microservices interacting with the Business Layer. It is noteworthy that all interactions with the Business Layer are continuously subjected to JWT guard validation.

For the final stage of the methodology, a review is carried out to evaluate the work carried out. Stakeholder feedback is collected and adjustments are made to the plan and tasks to adapt to changing needs.

4 Results

Comprehensive system testing was conducted to ensure its functionality and performance. Integration tests were carried out to verify the proper communication between companies and the central server through the GRPC and SSE protocols. Additionally, load tests were performed to assess the system's ability to handle a high volume of transactions and real-time updates in inventory management, order delivery, and the generation of visual reports using the intelligent inventory system. Here are some of the results.

4.1 Inventory Control

Inventory control was achieved using gRPC to capture product data within the inventory. This data was then sent in real-time via SSE for visualization and subsequent counting on the web page. The displayed data includes the product name and its quantity or stock.

In addition, you can see the options that encompass the entire inventory control process, as well as the save notification. To avoid keeping the communication channel open continuously, there are "start" and "stop" buttons to initiate and halt the SSE process, thus conserving resources.

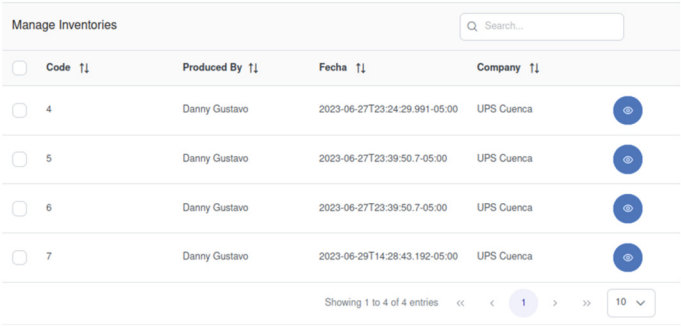

Fig. 2. Inventory Product Movement.

Once the inventory count is completed, the system proceeds to save this record with the current date and the responsible party using REST services in the database. This allows the generation of a list of all inventory counts, as visualized in Fig. 2, with the aim of achieving more efficient control. This list also offers search options, column organization, and access to the information contained within each record.

4.2 Distribution Route Generation

When the system registers a transfer order to an affiliated sub-company, previously registered with its geolocation coordinates and data, it can keep a record of all orders in a "completed" or "pending" state. This enables the system to filter pending orders through REST services. Additionally, there is an option to review order details, and most importantly, a button is displayed on pending orders to confirm their completion.

Once the orders to be delivered are obtained, the GPS coordinates of the customer, previously registered within the company's information, are retrieved. Using the Google Maps API, a delivery route is plotted, starting from the company's location and passing through the delivery points before returning to the company.

Next, in Fig. 3, the map display with the plotted route is presented. After completing the deliveries, the user can confirm them in the list as "completed," and the map will automatically update accordingly.

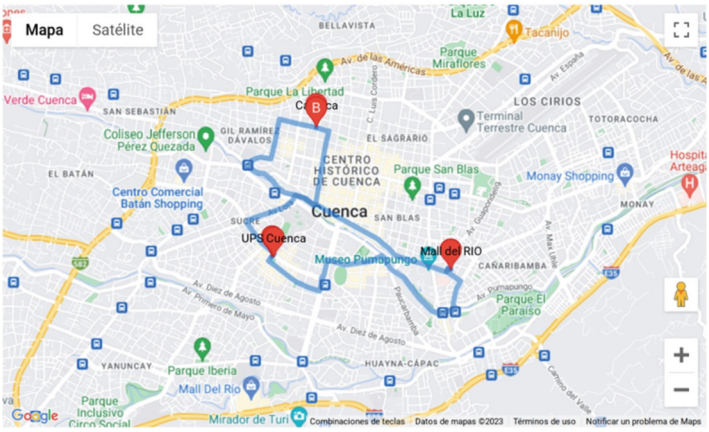

Fig. 3. Generation of Optimal Product Distribution Routes.

In Fig. 4, a bar chart will be generated to display the number of transactions completed per month. This chart will also include a comparison between the current year and the previous year, offering a longitudinal view of the company's activity. Additionally, there will be an additional panel showing the best-selling products of the current month, providing both the product name and the quantity sold. This information will be crucial for making decisions related to inventory management, production, and product marketing. Similarly, a chart displaying a trendline based on the data for the total monthly sales revenue up to the current point in the current year will also be visualized.

Finally, comprehensive unit tests were created for each of the system's components and functionalities to ensure that each unit of code functioned correctly on an individual basis. On this occasion, test cases were created to cover various scenarios in conjunction with other forms of validation. Unit tests contributed to the creation of a high-quality and reliable system for end users.

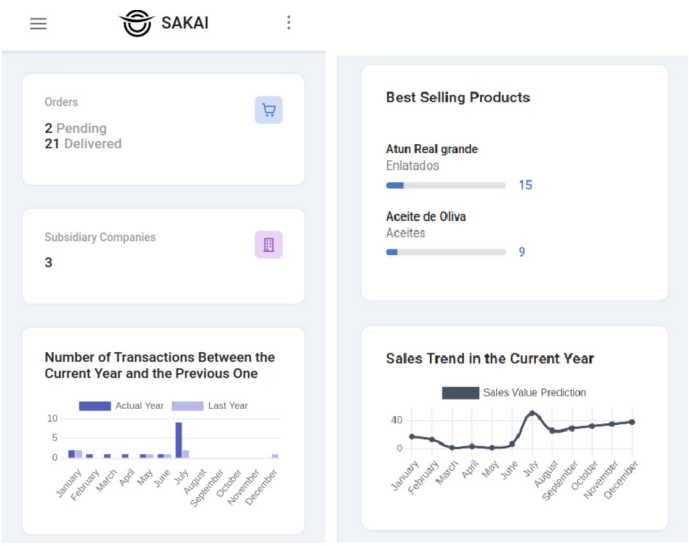

Fig. 4. Comparative Sales Charts, Best-Selling Products, and Trends.

The first test pertains to the operation of real-time data capture through the "start" button, stopping this process with the "stop" button, and using the "save" button to carry out the data storage process (Fig. 5).

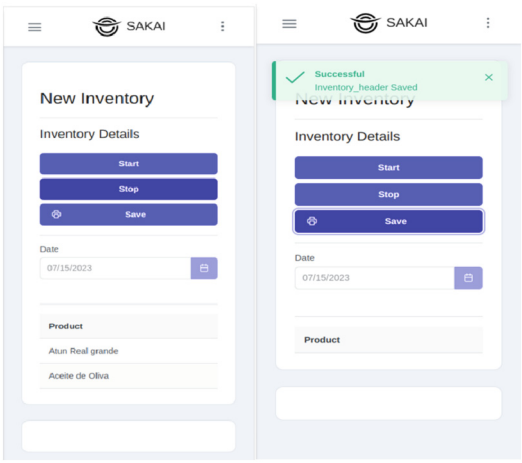

Fig. 5. Inventory Acquisition via the gRPC Protocol.

The second test involves generating the distribution route when there are pending orders and automatically updating the map upon confirming an order using the "confirm" button in the record, as shown in Fig. 4.

Laboratory tests were conducted using synthetic data and simulations to validate system performance. These tests covered a comprehensive evaluation of the system's various functionalities, including inventory management, reporting, order management and inter-company synchronization. Synthetic data verified the system's ability to process inventory data, while functional testing evaluated its real-time capability while maintaining data integrity and information security. These procedures played an essential role in ensuring that the system met performance, reliability and security standards prior to deployment.

5 Discussion

The project described in this document addresses a series of challenges related to inventory management, routing, and the generation of descriptive reports within a business environment. This is achieved through the implementation of an agile methodology, such as SCRUM. The selection of SCRUM as an agile methodology was grounded in its ability to effectively address the dynamic and ever-evolving challenges present in the business environment. SCRUM is particularly notable for its flexibility and its focus on the iterative delivery of functionality, a feature deemed indispensable given the constantly evolving nature of inventory management and routing. While SCRUM emerged as the preferred choice, other agile methodologies, including Kanban and Lean, were also subject to consideration [14]. However, SCRUM is better aligned with the requirement for incremental development and adaptability in the face of ever-changing demands.

The system architecture was partitioned into three layers: the data layer, the business layer, and the presentation layer. This architectural decision was predicated upon the necessity for efficient management, effective interaction between the database and the application, and the transparent presentation of information to end-users [15]. While this architectural framework demonstrated its robustness in terms of scalability and maintainability, alternative options such as monolithic architecture or microservices architecture were subject to evaluation [16]. Nevertheless, the three-tier architecture emerged as the optimal choice, striking a suitable balance between simplicity and scalability. This proves indispensable in dynamic business environments where the volume of products and transactions can experience significant growth over time.

In the domain of real-time inventory management, gRPC and SSE were selected owing to their aptitude for delivering low-latency data transmission [17]. This choice was underpinned by the necessity to keep end-users updated in real-time regarding inventory changes. Comparative to alternative technologies, such as RESTful API or WebSockets, gRPC and SSE demonstrated enhanced efficiency in terms of latency. While these technologies were the chosen solutions, a comprehensive evaluation of other alternatives took place, culminating in the determination that gRPC and SSE were the most appropriate choices to ensure efficient real-time communication [18].

The generation of distribution routes is a competitive advantage as it allows for optimal routes for order delivery. This improves distribution efficiency, reduces delivery times, enhances customer satisfaction, and contributes to environmental sustainability [19].

Finally, the practical implications of this solution in the context of inventory management in various industries are mentioned. It can be applied across different sectors, such

as logistics, e-commerce, and manufacturing, where efficient inventory management is critical for operational success.

6 Conclusion

In this article, we explored various project phases related to inventory management, route generation, and report creation. We began with preliminary research into inventory management systems, the resources they use, and the technologies they employ. This research provided valuable insights and guided the direction of the system, emphasizing technologies that promote efficient data automation and processing.

As a result, we demonstrated an effective and beneficial solution in the realm of inventory management through this technological approach. It facilitated efficient and real-time communication between the involved companies and the central server, enabling precise inventory synchronization and more effective order management.

The use of GRPC and SSE protocols offered numerous advantages, including the ability to receive real-time inventory updates, thereby improving decision-making and preventing issues such as stock outs or duplicate orders. Additionally, the system's scalability was tested, allowing it to adapt as more companies were added without compromising performance.

The project also focused on generating delivery routes for pending orders. The system retrieved delivery point information and utilized Google Maps to visualize and optimize routes. It also included the creation of comprehensive reports and dashboards that provided valuable insights into various aspects of the company's operations, enabling administrators and managers to make data-driven decisions.

The rigorous testing conducted during development ensured the system's quality and reliability by identifying and rectifying errors in early stages. This contributed to a successful implementation and the delivery of a stable and problem-free system.

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A Dynamic Language System for Authoring Procedural Scenarios in Virtual Reality Environment Applications

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Abstract. VR (Virtual Reality) applications have been increasingly adopted in Industry 4.0 practices, and this is established with a perspective towards the future. One of the main pillars of VR concerns interactive features. However, for interaction in VR environments, it is necessary for the designer and/or programmer to face some challenges that are present in authoring processes. These challenges are problems that can be solved or minimized under VR design methods. It was proposed to develop a *programming language*, in high levels of abstraction, as an *authorial* interface for obtaining objective-oriented (procedural) scenarios of VR applications with interactive resources. To achieve this, three ecosystems fulfill the dynamic functionality of the *language*. This involves the formal notation of the *Linguagem_RV* language, a *compiler* (written in *.Net C#*), and an *application framework* (integrated with the 3D virtual environment engine, *Unity*). The effectiveness of the developed resources was validated, supplying concepts for VR *authoring* process optimization, considering a facilitated, responsive, and scalable solution.

Keywords: Authoring · Compilers · Industry 4.0 · Programming Language · Virtual Reality

1 Introduction

Virtual Reality (VR) technologies have been widely adopted in industrial processes and practices, specifically in the presentation and user interaction with three-dimensional (3D) Virtual Environment (VE) scenes. In [1], a moment is identified when the scenario approves its incursion, highlighting its influence on industry and leading to a search for ways to maximize the use and application of the technology. Thus, the popularity of VR applications has been growing over the years, becoming a major trend for the future. This scenario is established over terms of the industry 4.0 [2], when technology tends

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to evolve and the market, society, production systems (manufacturing and supply) and education also evolve as new needs, interests, and potentialities emerge among these sideways.

VR applications enhance cases and situations in the industrial environment, including the interests of their applicability to reproductions of simulation, training and education, operation and control, etc. [3]. Since a VR scenario does not involve life-threatening environments or risks, not even a real operating system, which are considered in practical conventional methods that are commonly used in the industry and in the rental of real resources, these resources allow for cost and risk reduction [4, 5].

Interaction is one of the main features desired in VR applications [6]. However, these resources are often defined at the functionality/execution level, making it impossible for potential users to make modifications to a scenario.

According to [7], with necessary arguments, despite recent advances in the field of software engineering, the development of VR applications is still considered a challenging task from both a theoretical and technical perspective. Thus, creating VR environments incurs costs, which often succumb to trivialities, involving aspects such as professional design capability, computational processing, financial costs, and the utilization and adaptation of ready-made resources. Because of this, it would be hard to rely on development teams frequently, which leads to complicated and expensive projects, time and money costs, and software solutions with low scalability.

Since the industry is a highly productive sector, it is essential for the software resources to be easily scalable, meaning that the applications interactions could be easily modified. In this context, many efforts are focused on the goal of facilitating the development of VR applications, aiming for the need for project decoupling, both in software and hardware, and the utilization of ready-made resources, eliminating the need to start from scratch [7].

Faced with a scenario of needs and potentialities, in the concerns of this work, arises an interest in a new interface for adding interactive resources in scenarios of VR environments, applied to the authoring process. This interface should provide a high level of abstraction, simplified syntax, generalization, and modularization of ready-made resources for procedural operations, such as for trivial or complex scenarios. This step is intended to improve the implementation of interactions in applications that are typically intended for the training operations. In this context, the development of a *programming language* specifically designed for making VR applications was proposed. This conveys something that does not exist already: a language for VR. Thus, a language system based on notation, *compiler*, *application framework*, and 3D VE engine were planned. It is intended for implementing interactive scenarios based on sequences of procedural subjects. To accomplish this, the methodological steps involve literature review, technology development, testing, validation, and results.

2 Literature Review

2.1 Virtual Reality

The types of VR are focused on Mixed Reality (MR), Virtual Reality (VR), and Augmented Reality (AR) [8, 9], forming a set of designations associated with the terms of XR (the XR technologies) [10]. The three mentioned realities are situated within a conceptual domain of virtuality [9]. Whereas in VR, the user tends to be immersed in computer-generated VE (like going into a 3D environment/reality) [8].

VR technology is an advanced interface for computer applications that allows users to navigate in real-time in interactive 3D VEs through multisensory devices for *activation* or *feedback* [3, 9]. It makes use of different devices and sensors to reproduce user output and track input [8]. The understanding of input and output is information echoed between the user and the processing of a 3D VE, connecting them to the sense of interaction, the user with virtuality, and vice versa – exploring human-computer interaction through an enhanced computational medium [11].

The integration of devices and sensors into VR systems allows for different degrees of freedom and immersion when reproducing and interacting with their applications. Users can view the presentation from a variety of angles and perspectives, as well as move in six directions: up, down, left, right, forward, and backward, enabling degrees of freedom based on the user's perspective with the virtual presentation [11]. They can control the virtual behavior of the virtual reproduction, activating dynamic behaviors. E.g., you can interact with a 3D model of a virtual object by grabbing, positioning, and releasing the object using, essentially, your hands, head, or eyes (whatever, depending on what technological functionality is available).

2.2 Programming Language Development

Before a *language* can be implemented computationally, it must first be conceived and defined, requiring an understanding of its functional capabilities (operations and data types), style/design (vocabulary), and efficiency (ease of writing and processing) [12]. Beyond language development theories, for a language to be formally defined, the main involved concepts must address *syntax* and *semantic notations* (defining structures and giving meanings to expected functionalities) [12, 13]. Therefore, the processes of conception, notation, and definition of these two structures (*syntactic* and *semantic*) are essential in the design of a language; as such as even the vocabulary, necessarily referred into *lexical* conveys (this is going to be relaxed on Compilers).

A formal *syntactic notation* was introduced in 1959 by Backus with BNF [12]. It can be said that the notation is what makes a language implementable by computer systems. Any *compiler* can be designed, however, regardless of its specificity, the language would still coincide the same functionality and *syntax* as designed. To ensure this coincidence in functionality, it is also necessary to reproduce notation regarding *semantic* properties. According to [12], the concept of formal *semantic notation* is based on McCarthy, but the first development of semantic definition was done by the IBM Vienna Laboratory. This method aims to solve the main problem in programming, which is to determine whether a program does what it is intended to do.

It is common and relevant to classify developed languages according to paradigms and forms of executing programs. So, computer languages can be pragmatically divided, and some known categories, according to [14, 15], include: imperative, declarative, functional, logic-based, object-oriented, Von Neumann-based, and scripting languages. Going to forms of executing programs, take note that it generally refers to *compilers.* And a compiler's way of solving programs at compile-time and run-time determines whether a language is *dynamic* or *static* [14]. Dynamic features are typically resolved during runtime. This approach poses challenges for a compiler implementation, often leading *dynamic languages* to use interpretation [16]. Additionally, it encourages the construction of *hybrid compilers*, where part of the program's execution is *compiled,* and another is *interpreted*.

2.3 Language Compilers

The concept of high-level *languages* and *compilers* is fundamental in the development of *programming languages*, playing an essential role in the history of languages [12]. In addition to what was seen in the last subsection, the *compiler* is the system responsible for translating the *source program* written in a given language into its corresponding *object program*, which has the purpose of execution.

The structure of a compiler consists of two main stages: *analysis* and *synthesis.* The analysis stages are referred to as the *front-end* of a compiler, and they involve *lexical*, *syntactic*, and *semantic analyzers*. On the other hand, the synthesis procedures are performed in the *back-end*, which includes the *semantic* stage [14].

The process of *lexical analysis* corresponds to the first phase of a compiler. The reading process essentially involves the expertise to distinguish a certain amount of linguistic symbols from streams of data (*chars*) and turn them into meaningful units of words (types or *tokens*), known as *lexemes*, corresponding to some *vocabulary* (a set of words and rules for forming those words). The lexical system acts strictly by correctly identifying the words of a language in any of its programs. Typically, rules can be described using *regular expressions* (smaller universes that make the types of arbitrary words predictable, if they match a pattern) [14].

The *syntactic analyzer* works with the stream of tokens produced by the *lexer*. It uses them to create an intermediate *tree* representation. This representation strictly relies on *grammar rules*, which define the structure of the language. In order to achieve this, the *syntactic* process commonly explores the topics of *context-free grammars* (rules for constructing language sentences) and *syntax trees* (structures that represent sentences evaluated against a grammar) [14].

A *semantic analysis* is used to handle the remaining constructions and conditions of the compilation process. It adds *context* to the grammatical sentence formed by a language and triggers subroutines of the compiler to process the constructions of an *object program.* For this purpose, a commonly used method is *syntax-directed translation* (deriving the received *syntax tree* from the syntactic analysis and performing validations and constructions from the *source program* to the *object program*) [14].

The development of compilers is often viewed as a complex endeavor. However, there are ready-made software solutions that aid in generating the processing structures of compilers for languages. *Analyzer / Parser generators* are software tools that can

automatically implement them. E.g. [14]: *Yacc*, *Bison*, and *CUP* (grammatical sentences by *bottom-up parsing*); or *Antlr* and *LLGen* (*recursive descent parsing*).

3 Related Works

In this section, we will present some references from the literature that also propose optimization of VR application *authoring*. These proposals examine the development of design models commonly associated with the core of the application, such as abstract programming interfaces, frameworks, software architectures, and even optimized workflows for teams and processes.

The works [17, 18] propose *frameworks* for optimizing the *authoring* processes of VR applications, specifically for training and/or operation in industrial environments. These *frameworks* are based on concepts of generalization and resource utilization, aiming to enable the generation of applications with minimal effort or dependency on software developers. They also facilitate technical experts from the industrial sector to modify or implement their own scenarios. Both *frameworks* incorporate a data-oriented graphical representation interface.

In [17], their focus was primarily on demonstrating the architecture of their *framework*, *INTERVALES*. That was based on UML modeling, focusing and establishing data on the representation of functional modules for describing and representing application scenarios and states. The work also described the entire *workflow* involved in creating scenarios for VR applications, thus achieving the proposed ecosystem.

Complementary, the work presented in [18] explores the need for a *compiler* in the *authoring* process, beyond *framework* architectures. Although the development of the *framework* is still essential, in a proposal like this, it was possible to notice not only the presence of a *framework* and/or data model (architecture and design), but also a *compiler* for optimizing the *authoring* process of VR applications.

According to the work presented in [19], there is a need for effective *authoring* tools and a lack of well-defined development standards. The paper introduces a VR *authoring* tool, *CAVE-AR*, and proposes a *workflow* focusing on deployment and generation of application scenarios, optimizing project costs.

In this context, by Table 1, based on references, it is possible to relate the importance of project architectures to creating scenarios of VR apps. Based on *framework* and *workflow* features. So, by having a structure based on a formal language (data-oriented, even a graphical interface), with well-designed *framework* software ecosystems and *workflows*, authoring VR would have been optimized.

Furthermore, a contrasting step is presented in [18] with the proposal of compiler; until that point, there was no comparable understanding of optimization in literature. This idea also applies to this work. However, it is worth noting that none of the proposals aim at *compilers* for general-purpose *programming languages*. Hence, in this paper, there is potential for exploring the domain of *programming language* computing within this *compiler* proposal.

Table 1. Proposals for optimization in the related scenario (a narrative resource).

Works	Framework	Workflow	Compiler	Interface
[17]	yes	yes	no	data-driven
[18]	yes	yes	yes	data-driven
[19]	-	yes	no	-

4 Conceptual Architecture

The proposed VR authoring system's conceptual architecture was founded on the graphical representation depicted in Fig. 1. The *language* was initially named *Linguagem_RV*. In the *authoring* process of an application, there will be three ecosystems: *application framework* (which communicates with an engine environment); *compiler*; and *language program* (source, object/implementation, and running).

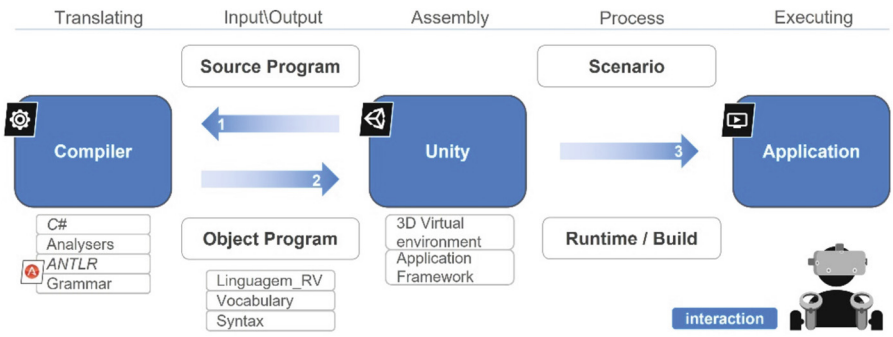

Fig. 1. Integration and Pipelines of the technologies in the VR *authoring* (*Linguagem_RV*).

The *application framework* will manage the interaction between the *object program* of the language and the events of a reproduced VR scenario, thereby transmitting, receiving, and intercommunicating data with the application VE. To develop the *framework*, it will be used the API provided by a commonly 3D VE engine. This is a commonly employed software architecture, as seen in proposals such as [17, 18]. To accomplish this objective, it will be executed through the utilization of *C# scriptings* and seamlessly integrated with the API of the *Unity* engine.

The *compiler* system should implement stages of analyzers on a source program of the language. The intended processing will perform *syntax-directed translation*, making *lexical* work by itself, and using the *Antlr tool* for *syntactic* structure (which generates a *syntax tree*) and the basis for *semantic* processing (utilizing the *Visitor pattern*). An object program is generated in the previously defined language object, C# (the same as the compiler – as a *hybrid*, a *high-to-high* level). The idea that the compiler is hybrid arises from the fact that it does not compile the program into assembly code, but rather into an intermediate object called the *language object* (runtime-used).

The *compiler* should be an entirely independent external library from the engine (*Unity*). This directive would allow the *compiler* feature to be integrated with other 3D VE engines. Reducing the burden on the *framework* and increases the portability of the *compiler* and, consequently, the *language*, making the features responsive and decoupled (scalable). For this purpose, that will utilize the *.NET netstandard 2.1* base-*compiler*, which by default targets the compilation of the *C#* language (v. 8.0).

The initial conceptualization of the action interaction techniques of the language aimed to implement intricate behaviors between the scenario and the user, as well as the presentation and validation of interactions with VR application scenarios. It sought methods of interaction between the operational contexts of route (e.g., getting to a place, like moving to it), interaction (e.g., picking up an object), and presentation (e.g., showing a dialog). However, the proposal will be limited in scopes, focusing solely on the reproduction of route interactions.

According to Fig. 1, the intended processing flow indicates that the *application framework* activates the *compiler* by sending it a *source program* written on *Linguagem_RV*. This program is then processed, translated, and "assembled" into the *language object*. When received by the *application framework*, this *language object* allows its implementation in the existing 3D VE scenario of *Unity*. The processing occurs during executing an VR app, involving immersive presentation and interaction, integrating the functionality of the *language object* between the *application framework* and a reproduced VR environment. This can be done either at runtime (debugging in the engine) or by generating a build (an executable) of the application.

5 Implementation, Functioning and Limitations

The goal was to develop the formal notation of the *language* (*Linguagem_RV*), the *compiler* system, the *application framework*, and the integration of these components into a complete language's VR ecosystem. Even though the *language* description isn't given, the process has been done. Language development techniques were employed, including defining an appropriate *vocabulary*, *grammar* (*syntax*), and *semantics*. Regarding the *compiler*, the *lexical*, *syntactic*, and *semantic analyzers* were implemented too. The *lexical* system was manually created; the *syntactic* and *semantic* systems were implemented using resources generated by the *Antlr tool* (*grammar*, *syntax tree*, and *Visitor*), performing *syntax-directed translation* on constructing *language objects*.

The implementation process of the software solution was divided into prototypical steps. At each step of the *language* solution, the feasibility of implementing a new feature was evaluated. One of the noteworthy features was the capability to incorporate a *compiler* and a *framework* into the 3D VE engine, and then to generate applications through the implementation of *Linguagem_RV* programs. The development process of both the *application framework* and *compiler* was conducted concurrently with the integration of the resources into the 3D VE (*Unity*).

5.1 Solution Steps

Among the interactive action features to be implemented by the *language*, only the route system was designed, thus becoming a validation requirement. Therefore, in each prototypical reproduction, the intention was to implement procedural scenarios of interaction actions focused on fulfilling route routines (the user should move from a specific position in the VR environment to another indicated destination region).

In step 1, all *compiler* program features were implemented within *Unity*. Consequently, the *language objects* were biased towards the *application framework*, making them relatively dependent on the engine's libraries (the *compiler* constructs programs within the *framework*). At this juncture, the *compiler* was capable of evaluating its language and environment support in conjunction with the *framework*.

In step 2, it was aimed at decoupling the language system from *Unity*. To achieve this, the *compiler* features were implemented as an external library. At this point, the *compiler* would have its own *language object* (although it was limited to data objects), without relying exclusively on the *application framework*. However, the interaction management feature was still implemented within the *application framework*. The goal was determining the necessity of this system truly being a process within the language itself, performed during each scene cycle within the language's own *object program* (decoupled of 3D VE engine's objects and libraries – self-managed).

In step 3, the entire language system's work was decoupled from the 3D VE tool, reducing the implementation requirements of the *framework*. To achieve this, all *language objects* were created directly within the architecture of the language *compiler* system. As a result, the *compiler* was able to construct a *language object program* that was fully based on a generic and scalable architecture of the *language* structures.

5.2 Functioning and Limitations

In the most recent integration, the system operates as follows: an *application framework* requests the assembly of a *source program* from its *Language_RV* compiler; the *compiler* then translates and returns the program, which is then integrated into the *framework* to facilitate communication between the program (*language object*) and the environment (3D VE scenario - *Unity*). Consequently, the *application framework* initiates a new processing cycle of the *language object* with each scene rendering cycle, thereby incorporating it into VR applications generated by the engine. Figure 2 illustrates the system based on real excerpts.

It was discovered that the implementation of the *language object* did not support the execution of the interactive scenario. This limitation was attributable to minor requirements in the architecture implemented in step 3. Coming from the fact that the *language object* was not designed based on the interface of generic classes provided by the *Unity* engine, and it also did not implement *serializable objects* or *attributes*. Even though the step 2 solution was not fully scalable, it was already possible to run the VR application, which indicated that the *language* worked.

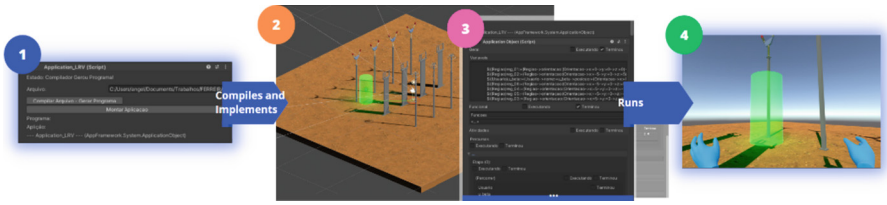

Fig. 2. Interfaces integrated in *application framework*: (1) *compiler* (compiling); (2) scenario (implementing); (3) *language object* (editor debugging); and (4) *VR app.* (running).

6 Validations and Results

6.1 Language Functionality

The objective was to evaluate the imperative nature and functionality of the language. A specific first-source program was used to validate the integration of the processing cycle between a *language object* and a 3D VE engine. This function increments the value of a variable by one. Another program was used to evaluate the imperative nature of the language. How feasible would it be for the language program to solve mathematical operations that could be integrated into a process within an application scenario? Invoking an interactive factorial function for the number 10.

The results demonstrated the effectiveness of the functional feature of the *language* based on the debugging of the evaluated operation state of the *language object* by *Unity* engine *Editor*. In the first program, it was observed that the variable value was incremented synchronously with the engine's processing cycles. In the second program, the precision of the returned value (3628800) was obtained after a period of 10 processing cycles. However, the language object proved to be functional and capable of integrating into the application's VR environment.

6.2 Authoring Process of VR

The aim was to evaluate the VR *authoring* process. That was to assess the cost relationships for assembling and implementing *language programs* and to determine whether the costs associated with a completely decoupled language program would impact the solution. Therefore, a comparison of the *authoring* process for the VR scenario, based on 60 interactions (routes), was analyzed and recorded in Table 2, comparing the coupled model (step 2) with the scalable model using the *language object* (step 3).

According to Table 2, it is observed that the *language object* generated by the *compiler* (step 3) does not incur relatively high costs. The measurements were extremely close (absolute difference in assembly data). The implementation in the reduced *framework*, with the scalable *language object*, transfers part of the implementation time (in the application) to the assembly (compilation) process, resulting in a comparatively reduced implementation time (absolute difference in implementation data). However, it is noteworthy that the complete authoring system (step 3) of the *language program* shows parity and lower cost (absolute difference in total). This indicates that the VR *authoring* resource based on *language* is fully viable.

Table 2. Comparative analysis of authoring costs in terms of time (s - seconds).

Works	Assembling (s)	Implementing (s)	Total (s)
Step 2 (5.1)	0,0815	0,0100	0,0915
Step 3 (5.1)	0,0852	0,0048	0,0900
|difference|	0,0037	0,0052	0,0015

7 Final Considerations and Future Works

Despite limitations and a scoped-down approach, it was possible to develop a *programming language* system, demonstrating effective potential to support the *authoring* process of procedural scenarios based on interactive activities in VR.

The language system's workflow still necessitates technical proficiency from the programmer, and the requirement for a 3D artist is imperative due to the 3D design aspect. Nonetheless, from a positive perspective, an adept technician may receive specialized instruction on the utilization of the *language* and be capable of modifying their own VR application scenarios. In a less likely scenario, at the very least, the *language* is designed to be straightforward for software developers, considering that the implemented architecture is optimized, user-friendly, responsive, and scalable.

Besides, the proposed solution has the potential to be utilized in principle for the creation and modification of training scenarios based on VR. In the context of industry 4.0, this system would enhance the feasibility of implementing VR technologies, given the flexibility and cost-effectiveness of their projects.

In conclusion, the developed system has demonstrated improvements in *framework*, *workflow*, and application, as well as innovation in the *compiler* system for *programming languages* for VR – it is optimization. Future works may include implementing serialization of *language objects*; exploring new methods of interactive actions; integrating graphical and/or immersive *authoring* interfaces; and, evaluating efficiency in more complex scenarios (theoretical time and memory costs), including the execution of the VR applications.

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Using 5G Technologies and Predictive Models to Achieve a Flexible Network Capacity in Supercomputing Centers

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Abstract. Supercomputing is a key enabling technology for most scientific disciplines: from physics to medicine and engineering. Thus, existing supercomputing infrastructures must attend a growing demand that can overpass the installed network capacity very easily. In this context, supercomputing centers usually must choose between two management policies: either assuming a loss in reliability and availability because of network congestion or implementing fair use policies to limit the free access to supercomputing resources. However, both have a negative impact on scientific production. Therefore, new innovative techniques to adapt the network resources in supercomputing centers to the demand at real time are required. In this paper we propose a solution to achieve a flexible network capacity in supercomputing centers, through time series prediction algorithms and ad-hoc 5G mobile communication interfaces. The individual traffic flow generated by every machine is predicted as a combination of three basic methods: polynomial fitting, time series decomposition, and Holt-Winters algorithm. This information is employed to detect future bottlenecks and congestion regions, using the teletraffic theory. When congestion is detected, an ad-hoc wireless 5G communication link is activated. A Particle Swarm optimization process is triggered to ensure the deployed 5G interfaces are technologically viable. An experimental validation based on simulation scenarios shows that supercomputing centers could support an increment in traffic up to 17%.

Keywords: 5G communications · supercomputing centers · time series · PSO · teletraffic · network simulation

1 Introduction

Supercomputing technologies are a key component for most scientific fields [1], where very complex simulations, numerical analysis, or large data processing is needed [7]. Science disciplines using supercomputers range from physics (where huge datasets from

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large scientific infrastructures must be curated) to engineering (where very precise simulations with thousands of variables [2] are required to build next-generation transport systems, architectonic projects, or power distribution networks). In this context, a much larger number of researchers is demanding access to those supercomputing resources than the target scientific community to which they were initially sized. Moreover, even in those supercomputing centers whose construction and design are much more recent, resources are rapidly overpowered by exponentially growing demand [3].

Although computing resources are the key element in supercomputing centers, network capacity is a critical parameter as well [4]. Supercomputing centers are basically large collections of networked machines, working together on a common task. It is essential that machines can communicate and exchange data through a reliable and high-capacity network [5], however in most common network topologies (e.g., fat-tree and Dragonfly) an oversubscription index is assumed [6]. This oversubscription prevents all the machines from consuming their available bitrate at the same time. Design principles say that the probability of this situation to happen is very unlikely. Nevertheless, as the demand increases, oversubscription situations are becoming more and more possible, making the available network capacity a limiting factor for seamless operations of supercomputing center.

Continuous expansion and updating of the network capacity is very costly and, in most cases, impossible [8]. Any additional network link may require the hard installation of new wires and network interface cards, plus server and router reboots. All these tasks will certainly impose a downtime on the operations of the supercomputing center, as they cannot be executed in a continuous process.

In that way, supercomputing centers must choose between two different alternatives to manage this increasing demand. Either they ignore excess demand and accept periodic congestion situations, or they implant fair use policies restricting the free access of researchers to supercomputing resources [8]. However, both solutions slow down scientific advances and innovations. In the first case, because congestion finally causes unavailability and a relevant loss in reliability. Researchers may have to repeat calculations or actively wait for congestion to mitigate. In the second case, researchers are provided with time slots, which may be insufficient for exploratory works that require continuous refinement.

As supercomputing is becoming increasingly more critical and essential for research work, new and innovative solutions are needed to ensure a flexible adaptation of the network capacity to the demand in real time. In this paper, we address this challenge. We propose a technology to achieve flexible network capacity in supercomputing centers based on ad-hoc 5G communication interfaces. Because of wireless interferences, a restricted number of 5G links can be established within a supercomputing center. To detect those critical congestion situations and bottlenecks in advance, we are using teletraffic theory. To feed the teletraffic models we are using a prediction scheme, composed of the weighted combination of three basic methods: polynomial fitting, time series decomposition, and Holt-Winters algorithm. A Particle Swarm Optimization (PSO) algorithm is triggered to ensure 5G communication links are deployed where the maximum impact in network capacity increase is achieved, provided they are technologically viable within the same supercomputing center.

The rest of the paper is organized as follows. Section 2 describes the state of the art in supercomputing center networking. Section 3 describes the main proposal including the prediction scheme, teletraffic models, and the PSO algorithm. Section 4 includes the experimental validation and the final results. Finally, Sect. 5 presents our conclusions.

2 State of the Art: Networking in Supercomputing Centers

Currently, supercomputers are still mostly developed by private companies, whose innovations are not usually publicly presented or disseminated. Thus, public and open research works on details about the architecture or behavior of networks in supercomputer centers are sparse. Gao et al. studied how networks can be fitted to support traffic in exascale computers [9], while Stunkel et al. focused on how terabit networks may be deployed using currently existing network devices [10]. But there are no details on the congestion situation and how they could be mitigated. On the other hand, works on the nature of congestion situations in supercomputing centers have also been reported [4]. The authors focus on congestion duration and causes, but no discussion about possible solutions is included.

Reported solutions for an increased network capacity are typically based on transforming the exiting deployment, so the installed capacity suffers a permanent increasing. For example, alternative routing protocols can be found to enable unused routes although they are not the shortest [11]. In addition, virtualization and containerization approaches are proposed [12], as well as the implementation of fully optical networks [13]. Similarly, approaches to redefine the multiple access policies, so they can become more intelligent and prioritize the most relevant traffic (integrating, for example, Markov chains) may be found [14]. However, in all these contributions, there is not a real adaptation to the real-time demand, but the installation of additional network capacity, which is expected to be above the future traffic forecasts.

Regarding 5G networks, some authors have explored capacity adaptation schemes to allow the coexistence between 5G communications and other wireless applications [16]. But those works put the focus on physical interferences, not on bottlenecks and congestion caused by packet flows.

In a more general analysis, several proposals for traffic prediction in data networks have been reported in the last five years. Although techniques based on standard technologies, such as graphs [15] or numerical models [17] may be found, most works are currently supported by Artificial Intelligence (AI) algorithms. Long short-term memory models [18], deep learning [19] or recurrent neural networks [20] have been explored. Nevertheless, all these models are later only employed for network optimization, while network capacity adaptation is not addressed. Our proposal fills this gap.

3 Flexible Network Capacity in Supercomputing Centers

A supercomputing center is a collection of S different machines, organized in N_{pod} different pods, and interconnected (typically) in a fat-tree topology (see Fig. 1). Every machine generates an instant data flow $s_i[n]$, , whose historical evolution can be understood as a time series (1). Also, being n the discrete time variable and N_{day} the number

of discrete time instants within a working day. Traffic flows $x_j^k[n]$ to be handled by the j-th device in the aggregation layer of the k-th pod can be calculated as shown in (2). Similarly, flows $y_m[n]$ to be served by the m-th router in the core layer can be calculated as shown in (3). Every link in the supercomputing center has a nominal bitrate (capacity), C_i, C_j^k and C_m for the pod, aggregation, and core layers, respectively. This nominal capacity could also evolve over time, if any infrastructure upgrade is applied. We assume that all routes have the same probability.

$$s_i[n] = \{s_i[1], \ldots, s_i[n-2], s_i[n-1], s_i[n]\} \tag{1}$$

$$x_j^k[n] = \begin{cases} s_{4k-5+2j}[n] + s_{4k-4+2j}[n] \ \textit{if} \ j \in \{1,2\} \\ \frac{1}{2}\left(x_1^k[n] + x_2^k[n]\right) \ \textit{if} \ j \in \{3,4\} \end{cases} \tag{2}$$

$$y_m[n] = \begin{cases} \sum_{r=1}^{N_{pod}} x_3^r[n] \ \textit{if misodd} \\ \sum_{r=1}^{N_{pod}} x_4^r[n] \ \textit{if miseven} \end{cases} \tag{3}$$

As all the historical evolution of all these traffic flows can be considered a time series, future required network capacity can be predicted, and with this information, congestion can be detected (Sect. 3.1). Later and eventually, an optimum 5G deployment can be activated to mitigate those bottlenecks (Sect. 3.2).

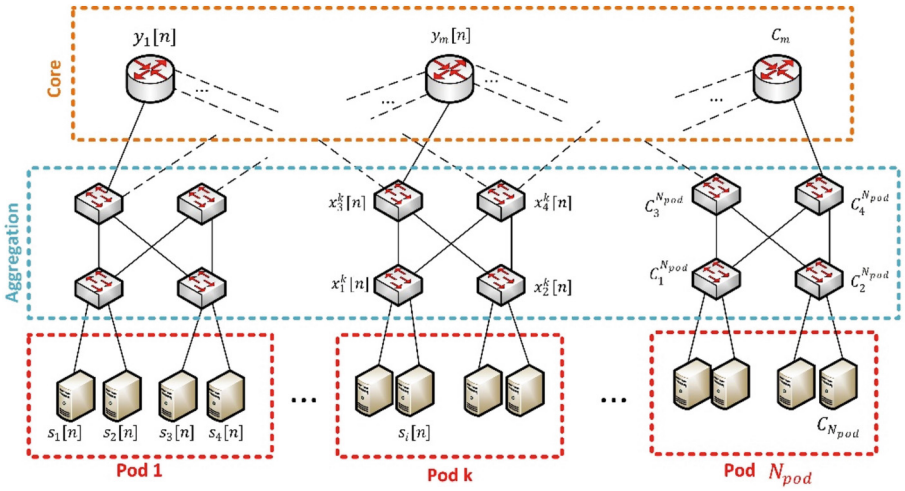

Fig. 1. Supercomputing center architecture

3.1 Traffic Prediction Model and Congestion Detection

In general, traffic tends to follow a stationary evolution: every working day, the peaks and valleys follow the same structure (approximately). Thus, analytic (and very precise)

methods could be employed for future value prediction. However, other short-term effects are also present in these time series. Therefore, numerical approaches could also show good behavior for traffic prediction. Then, future values for instant data flows $s_i[n]$ are obtained as the combination of three partial predictions (4). First, $f^i_{poly}[n]$ represents a polynomial model. The model is calculated by fitting algorithms from the daily historical evolution. Second, $f^i_{deco}[n]$ is a prediction based on a standard time series decomposition, where tendency, stationarity, and irregularity are obtained from historical data and later used for predictions. Finally, $f^i_{HW}[n]$ is a function obtained through the Holt-Winters exponential smoothing method. Variables λ_1, λ_2 and λ_3 are just weighting parameters, taken values in the interval [0, 1].

$$s_i[n] = \lambda_1 \cdot f^i_{poly}[n] + \lambda_2 \cdot f^i_{deco}[n] + \lambda_3 \cdot f^i_{HW}[n] \tag{4}$$

Function $f_{poly}[n]$ is calculated by multiple linear regression. In this model, traffic flow is a polynomial function of discrete time (5) with order R. Parameters β_r are calculated by minimizing the Mean Square Error (MSE) between analytical values and historical data (6). We assume the same traffic behavior will be maintained in the future, and function $f^i_{poly}[n]$ turns a prediction model.

$$f^i_{poly}[n] = \sum_{r=0}^{R} \beta_r \cdot n^r \tag{5}$$

$$\underset{r=0,\ldots,R}{\beta_r} = \underset{\substack{b_r \\ r=0,\ldots,R}}{min} \left\{ \frac{1}{n} \sum_{q=0}^{n-1} \left(s_i[q] - \sum_{r=0}^{R} b_r \cdot q^r \right)^2 \right\} \tag{6}$$

Function $f^i_{deco}[n]$ is calculated as the addition of three other partial functions (7). Namely: tendency $t_i[n]$, stationarity $s_i[n]$, and irregularity $i_i[n]$. Tendency is the smooth long-term behavior and it is calculated following an evolutive approach, as the mobile average of order three (8). On the other hand, stationarity (9) is calculated as the difference between the global mean of all historical data and the mean of the stationary period (one working day in our case, as said before). Finally, the irregularity is a random variable (10). It follows a Gaussian distribution whose mean and standard deviation is obtained from irregular components in historical data (11).

$$f^i_{deco}[n] = t_i[n] + s_i[n] + i_i[n] \tag{7}$$

$$t_i[n] = \frac{s_i[n-3] + s_i[n-2] + s_i[n-1]}{3} \tag{8}$$

$$s_i[n] = E\{s_i[n - q \cdot N_{day}]q = 1, \ldots \infty\} - E\{s_i[q]q = 0, \ldots, n-1\} \tag{9}$$

$$i_i[n]N(\mu_i, \sigma_i) \tag{10}$$

$$\begin{aligned} \mu_i &= E\{(s_i[q] - s_i[q] - t_i[q])q = 0, \ldots, n-1\} \\ \sigma_i &= E\left\{(s_i[q] - s_i[q] - t_i[q] - \mu_i)^2 q = 0, \ldots, n-1\right\} \end{aligned} \tag{11}$$

Finally, function $f^i_{HW}[n]$ is obtained by the direct application of the Holt-Winters exponential smoothing method. This method is useful for predictions, when time series have a tendency and stationarity. Function $f^i_{HW}[n]$ is then understood as the combination of three subfunctions (12): the estimated level $l_i[n]$, the estimated trend $B_i[n]$, and the seasonal variation $S_i[n]$. The first function to be calculated in this model is the estimated level $l_i[n]$ (13). In this model, variable α is a weighting parameter. Then, the estimated trend $B_i[n]$ can be computed (14). Where γ is, again, a weighting parameter. Finally, the seasonal component $S_i[n]$ may be obtained (15), using δ as control parameter.

$$f^i_{HW}[n] = (l_i[n-1] + B_i[n-1]) \cdot S_i\left[n - N_{day}\right] \tag{12}$$

$$l_i[n] = \alpha \cdot \frac{s_i[n]}{S_i\left[n - N_{day}\right]} + (1-\alpha) \cdot (l_i[n-1] + B_i[n-1]) \tag{13}$$

$$B_i[n] = \gamma \cdot (l_i[n] - l_i[n-1]) + (1-\gamma) \cdot B_i[n-1] \tag{14}$$

$$S_i[n] = \delta \cdot \frac{s_i[n]}{l_i[n]} + (1-\delta) \cdot S_i\left[n - N_{day}\right] \tag{15}$$

But Holt-Winters method is recursive, and initial values must be generated. The initialization point (16) can be calculated from the historical data, where R_{max} is the number of historical samples to be considered.

$$\begin{gathered} l_i[0] = E\left\{s_i\left[n - q \cdot N_{day}\right] q = 1, \ldots \infty\right\} \\ S_i[0] = s_i[0] - l_i[0] \\ B_i[0] = \frac{1}{R_{max}} \sum_{r=0}^{R_{max}} \frac{s_i\left[(r+1) \cdot N_{day}\right] - s_i\left[r \cdot N_{day}\right]}{N_{day}} \end{gathered} \tag{16}$$

By combining these elemental traffic predictions, future traffic flows can be calculated for all links within the supercomputing datacenter considering the fat-tree topology (2–3).

In teletraffic theory, it is possible to calculate the congestion indicator $\boldsymbol{\rho}$ as the ratio between the input and the maximum output data flows (17). In this case, we must consider that no link can manage more traffic than its nominal capacity.

$$\begin{gathered} \rho_i[n] = \frac{s_i[n]}{C_i[n]} \\ \rho^k_j[n] = \frac{x^k_j[n]}{C^k_j[n]} \\ \rho_m[n] = \frac{y_m[n]}{C_m[n]} \end{gathered} \tag{17}$$

Later, and using the congestion parameter ρ, it is also possible to calculate the structural loss probability P_L (18). Although packet losses are always possible and probable, because of congestion, queues in network devices may overflow, and structural losses appear. To calculate the loss probability P_L we are assuming queues have a capacity of

M_{queue} packets.

$$
\begin{aligned}
P_L(i)[n] &= \frac{(\rho_i)^{M_{queue}}}{M_{queue}! \cdot \sum_{r=0}^{M_{queue}} \frac{(\rho_i)^r}{r!}} \\
P_L(j,k)[n] &= \frac{\left(\rho_j^k\right)^{M_{queue}}}{M_{queue}! \cdot \sum_{r=0}^{M_{queue}} \frac{\left(\rho_j^k\right)^r}{r!}} \\
P_L(m)[n] &= \frac{(\rho_m)^{M_{queue}}}{M_{queue}! \cdot \sum_{r=0}^{M_{queue}} \frac{(\rho_m)^r}{r!}}
\end{aligned}
\tag{18}
$$

If congestion indicator or loss probability are higher than the given thresholds, ρ_{th} and P_L^{th}, mitigation actions are needed. And the procedure to deploy additional ad hoc 5G communication links is triggered.

3.2 5G Communication Deployment

5G mobile technologies are supported by a new radio interface, known as New Radio (NR). This wireless interface is based on OFDM (Orthogonal Frequency-Division Multiplexing) modulation and two different frequency bands. The Frequency Range One (FR1) belongs to the traditional sub-GHZ frequency bands (below 6 GHz), but its performance is limited. Thus, 5G ad hoc links in this work are working on the Frequency Range Two (FR2), belonging to the Ka-band (26.5–40 GHz). 5G radio channels in the FR2 can employ four different bandwidths: 50 MHz, 100 MHz, 200 MHz, and 400 MHz. In addition, three different carrier frequencies may be considered: 27 GHz, 28 GHz, and 29 GHz. Then, every network device can take thirteen different states, u_r: no 5G interface added, and twelve more states corresponding to all possible combinations of the four different 5G bandwidths and three carries frequencies that can be considered for any deployed 5G ad hoc link. Hereinafter, state "no interface" is represented by null value (zero), while integer values in the interval [1, 3] represent links with a bandwidth of 50 MHz centered in the 27 GHz frequency. Integer number in the intervals [4, 6], [7, 9] and [10, 12] have the same meaning for 100, MHz, 200 MHz and 400 MHz bandwidths.

The relation between the radio bandwidth and the effective bitrate C_{eff} is provided by the second Shannon's law (19). Where W is the link's bandwidth and P_o represents the transmitted power. Finally, N_o represents the radioelectrical noise in the environment.

$$
C_{eff} = W \cdot log_2\left(1 + \frac{P_0}{N_0}\right) \tag{19}
$$

Assuming no other wireless system is deployed in the supercomputing datacenter, and considering that thermal noise is negligible against any other noise source, power N_o is fully caused by intra-system interferences (i.e., interferences between 5G links within the datacenter). This interference can be calculated using the Friis formula (20), where $d(i_1, i_2)$ represents the physical distance between i_1-th and i_2-th machines, $f_{carrier}$ is the frequency of the carrier, c_0 is the light speed in free space, and $G(i_1)$ and $G(i_2)$ the antenna's gain in i_1-th and i_2-th machines.

$$
N_0(i_1, i_2) = P_0 \cdot G(i_1) \cdot G(i_2) \cdot \left(\frac{\frac{c_0}{f_{carrier}}}{4\pi \cdot d(i_1, i_2)}\right)^2 \tag{20}
$$

This interference is only relevant for links that use the same carrier frequency. In fact, all links operating at the same frequency interfere with each other at the same time. So, the global noise power N_o must be calculated as the addition of all individual contributions (21).

$$N_0(i_1) = \sum_{\substack{\forall i_2 \\ \vdots \\ u_{i_1} = u_{i_2}}} N_0(i_1, i_2) \tag{21}$$

Once these ad hoc 5G interfaces are deployed, the old (wired) nominal capacity $C_r[n-1]$ of the affected network devices is increased (additive relation) according to the effective capacity of the new 5G link (22).

$$C_r[n] = C_r[n-1] + C_{eff} \tag{22}$$

Then, the 5G deployment problem consists of finding the optimum state u_r for every network device, so the congestion indicator and the loss probability are minimum. However, this deployment must also be as minimal as possible, so that the network cost remains low as well. This optimization objective can be represented by function $F(\vec{u})$, where $\vec{u}$ is the collection of all network devices state (23), and μ_1, μ_2 and μ_3 are control parameters to strengthen some optimization variables over others. $U[\cdot]$ is the Heaviside step function.

$$F(\vec{u})[n] = (\rho_{\vec{u}})^{\mu_1} \cdot (P_L(\vec{u}))^{\mu_2} \cdot \left(\sum_{\forall u_r \in \vec{u}} U[u_r - 1] \right)^{\mu_3} \tag{23}$$

To solve this problem, we use the Particle Swarm Optimization (PSO) algorithm. In this algorithm, the network devices state u_r is updated in Q_{iter} consecutive iterations using a simple movement equation (uniform linear motion). We name q the current iteration, u_r^{best} the best device state ever calculated according to function $F(\vec{u})$, and u_{global}^{best} the best set of states for all network devices ever calculated according to function $F(\vec{u})$. Any particle (network device) may take values in the interval [0, 12] as described above (24). Additionally, variables $\varepsilon_{(0,1)}^{1,2,3}$ are random numbers whose probability distribution is uniform in the interval [0, 1]. Finally, ω_{min}, ω_{max} and $\theta_{1,2}$ are configuration and control parameters (25).

$$u_r \in [0, 12] \tag{24}$$

$$\begin{gathered} u_r^q = u_r^{q-1} + \eta_r^q \\ \eta_r^q = \begin{cases} \lfloor \varphi_r^q \rfloor \ if \ \varepsilon_{(0,1)}^3 < \frac{1}{2} \\ \lceil \varphi_r^q \rceil \ otherwise \end{cases} \\ \varphi_r^q = \theta_1 \cdot \varepsilon_{(0,1)}^1 \cdot \left(u_r^{best} - u_r^{q-1} \right) + \theta_1 \cdot \varepsilon_{(0,1)}^2 \cdot \left(u_{global}^{best} - u_r^{q-1} \right) + \omega_q \cdot \eta_r^{q-1} \\ \omega_q = \omega_{max} - \frac{q \cdot (\omega_{max} - \omega_{min})}{Q_{iter}} \end{gathered} \tag{25}$$

The points where ad hoc 5G mobile interfaces must be deployed, and their configuration, are finally calculated after the PSO algorithm completes all the Q_{iter} iterations.

4 Experimental Validation: Simulation and Results

In order to evaluate the performance of the proposed solution for a dynamic network capacity in supercomputing centers, we designed and conducted an experimental validation. Experiments were supported by simulation tools described through MATLAB scripts. The MATLAB 2022a suite was used as a simulation framework and numerical engine. All simulations were performed using a Linux server (Ubuntu 22.04 LTS) with the following hardware characteristics: Dell R540 Rack 2U, 96 GB RAM, two processors Intel Xeon Silver 4114 2.2G, HD 2TB SATA 7,2K rpm.

The proposed simulation scenario represented a supercomputing center organized according to an orthogonal layout. Eleven thousand machines in a fat-tree network topology were simulated. Data packets are randomly generated according to a Poisson distribution. The mean bit rate is adjusted to real bitrate measurements taken from our corporative (university) network. The nominal capacity of every communication link is selected to be consistent with commercial equipment, such as Juniper MX80 routing platforms. A 1:40 oversubscription ratio was considered too. In these conditions, congestion and packet losses appear on a random basis. Communication links were simulated using the MATLAB 5G toolbox and the TCP/IP communication toolbox.

Two different scenarios were considered. In the first one, no congestion mitigation algorithm was implemented. In the second, the proposed solution for flexible network capacity in supercomputing centers was programmed and running. In both cases, the total traffic managed by the supercomputing center was monitored and evaluated.

Every simulation represented seventy-two hour of network operations. One hundred and twenty simulations were performed for each different scenario. Results of the traffic supported are displayed in boxplots in Fig. 2.

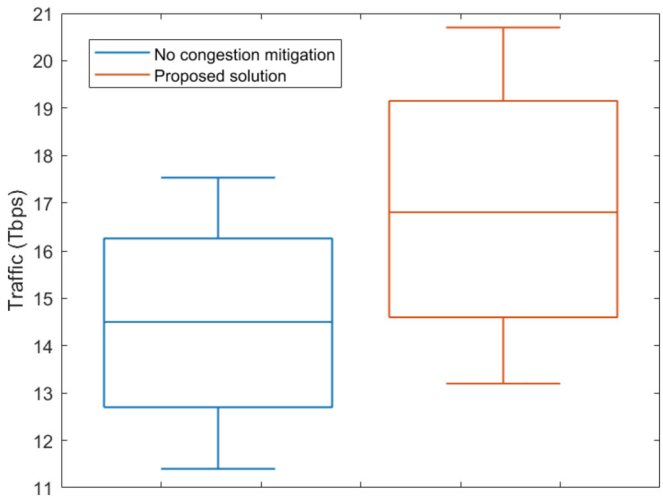

Fig. 2. Experimental results

As can be seen, all relevant values are higher when the proposed solution is implemented. In general, the minimum, average, and maximum values are around 17% higher in the scenarios where the proposed solution was running. This is the first evidence that the proposed solution for a flexible network capacity in supercomputing centers is successful. However, since boxplots are overlapped, a final conclusion of which results are better must be provided by a statistical test. In this case, we used the Mann-Withey U test [21]. Through this test we found that the proposed solution gets a better performance in supercomputing centers with a significance $p = 0.00033$ (very significant improvement).

5 Conclusions and Future Works

In this paper, we propose a solution to achieve a flexible network capacity in supercomputing centers, through time series prediction algorithms and ad-hoc 5G mobile communication interfaces. The individual traffic flow generated by every machine is predicted as a combination of three basic methods: polynomial fitting, time series decomposition, and Holt-Winters algorithm. This information is used to detect future bottlenecks and congestion regions, using teletraffic theory. When congestion is detected, an ad-hoc wireless 5G communication link is activated. A Particle Swarm optimization process is triggered to ensure that the deployed 5G interfaces are technologically viable. An experimental validation based on simulation scenarios is provided. Results show the supported traffic by supercomputing centers may increase up to 17%.

Future works will evaluate the proposed solution in real scenarios, including physical network devices.

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Implementation of Euclidean Clustering for Object Detection Using 3D LiDAR in an Autonomous Vehicle Prototype with Embedded System and ROS

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Abstract. In the pursuit of advancing autonomous driving and automation across various domains, precise obstacle detection stands as an essential feature. Leveraging LiDAR (Light Detection and Ranging) technology, renowned for its ability to provide intricate three-dimensional environmental insights, this article delves into a comprehensive methodology for obstacle detection and tracking. This methodology encompasses key aspects including point cloud preprocessing, segmentation, clustering, and obstacle tracking, all of which collectively contribute to a meticulous and robust perception framework. The article also underscores the merits of deploying a functional prototype and harnessing the potential of the Robot Operating System (ROS) to bolster environmental perception, enabling real-time testing and experimentation. The synthesis of these components not only substantiates the effectiveness of our approach but also highlights its potential implications in enhancing safety and decision-making within autonomous and automated systems.

Keywords: Obstacle Detection · Euclidean Clustering · 3D LIDAR · Point cloud Data · Detection and Ranging · Robot Operating System

1 Introduction

In the pursuit of advancing towards autonomous driving and automation, precise obstacle detection stands as a fundamental pillar in this field. The capability of a system to identify and track objects in complex environments is essential to ensure safety and efficacy in applications such as autonomous vehicles and mobile robotics [1,6]. The use of Light Detection and Ranging (LiDAR) technology has gained prominence in this domain, as it provides a detailed three-dimensional view of the surrounding environment. However, real-time obstacle detection and tracking pose significant challenges that demand innovative methodological approaches.

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1.1 Current Research

The research in [8] addresses LiDAR point cloud clustering, a critical component in applications like object detection and recognition. The authors introduce a method for automatically estimating the tuning parameters of DBSCAN (Density-Based Spatial Clustering of Applications with Noise), eliminating the need for manual selection. Their approach, evaluated using the KITTI dataset, demonstrates comparable results to the original DBSCAN. This adaptability to dynamic environments, such as robotics and autonomous driving, with individual parameter adjustment for each point cloud frame, opens avenues for further enhancement of the methodology's robustness and precision.

In [4], an algorithm for segmenting individual trees from aerial LiDAR point cloud data is presented. The methodology employs the local maximum method for initial segmentation and excludes misidentified trees. Utilizing the spatial distribution of point clouds and their relationships with other trees, a point cloud clustering method is formulated to identify individual trees effectively.

The study in [10] introduces an efficient point cloud segmentation algorithm that encompasses both ground and non-ground target segmentation. This method combines Euclidean distance and angle thresholds to address over segmentation concerns. Experiments with the KITTI dataset validate its faster execution speed and improved segmentation accuracy, even for sparse point clouds. Future work will extend its capabilities to obstacle recognition and tracking, offering improved accuracy and efficiency in point cloud data clustering and segmentation for autonomous vehicles and robotics.

In [9], the "Fast Channel Clustering" (FCC) algorithm is proposed for LiDAR point cloud clustering. FCC efficiently segments and merges point clouds in both horizontal and vertical dimensions by combining intra-channel and inter-channel grouping. It outperforms existing methods in object instance performance and is known for its hardware efficiency, with successful implementation on Field Programmable Gate Array (FPGA) hardware, significantly accelerating execution compared to CPU. In summary, FCC offers efficient LiDAR point cloud clustering and holds promise for enhancing perception in autonomous vehicles and robotic systems.

1.2 Contribution and Outline

This article focuses on a comprehensive methodology for detecting and tracking obstacles in three-dimensional environments using LiDAR technology. Our methodology addresses the crucial aspects of point cloud clustering, bounding box generation, and obstacle tracking to achieve accurate and robust perception. Furthermore, we delve into the advantage of implementing a functional prototype and integrating the ROS platform to enhance environmental perception and enable real-time testing.

The aim is to demonstrate the feasibility and efficiency of our approach in addressing key challenges in real-time perception of moving objects. Through a step-by-step process, from point cloud preprocessing to segmentation, clustering,

and obstacle tracking, we aim to provide a detailed understanding of each stage and its contribution to the final outcome.

The structure of this paper is organized as follows: in Sect. 2, the proposed method is presented. In Sect. 3, point cloud preprocessing is described. Section 4, the segmentation process is presented results and discussion are presented in Sect. 6. Finally, the conclusions of this study are presented in Sect. 7.

2 Proposed Method

In this section, a comprehensive analysis of the employed techniques will be conducted, along with the presentation of the symbols table and respective descriptions of each utilized algorithm, along with the corresponding nomenclatures. To facilitate understanding, an infrastructure diagram is included, illustrating how our system is composed to execute the processing outlined in this article.

Additionally, a process diagram will be shown, reflecting the methodology pursued in the creation of this document. This diagram will provide an intricate view of the algorithms, encompassing their sequential implementation and the manner in which contributions from the preceding algorithm influence the subsequent one. This process contributes coherently and robustly to the attainment of the final results.

2.1 Infrastructure

The infrastructure employed for this study involves harnessing a prototype vehicle, presented in Fig. 1, equipped with an industrial-grade computer and a 16-laser LiDAR sensor. This configuration enables the real-time acquisition of data from the LiDAR, which is subsequently published within the ROS [3] environment as a dedicated node. Through Ethernet connectivity, we establish a connection between an embedded Nvidia Jetson Xavier AGX unit, serving as the slave, and the vehicle, acting as the master. The Nvidia Jetson Xavier AGX unit assumes a central role, becoming the core responsible for executing the proposed methodology outlined in this research.

It is noteworthy to emphasize the bidirectional nature of ROS, where the processed LiDAR information can be reintroduced into the ROS ecosystem as a node. These data can be assimilated and interpreted by the autonomous vehicle prototype, thereby concluding the cycle of information exchange and computational execution within this autonomous system framework.

A clearer visual representation of this structure can be appreciated in “Fig. 2” presented below.

2.2 Data Processing and Analysis

In the Data Processing and Analysis section, a comprehensive breakdown of the methodology employed in this research will be provided. The steps taken for

Fig. 1. Prototype.

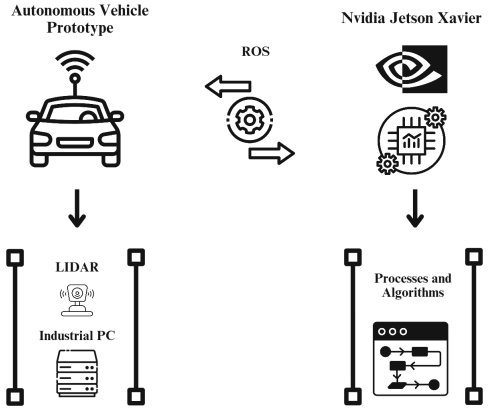

Fig. 2. Infrastructure Diagram.

data processing will be described, along with the technique used for cluster segmentation. This will be illustrated in Fig. 3, which presents a diagram outlining the phases implemented in this study. Each of these phases will be addressed in detail within their respective corresponding sections.

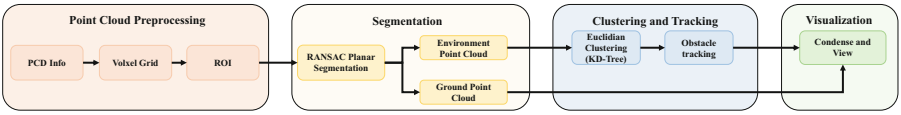

Fig. 3. Data Processing and Analysis Diagram.

As seen in Fig. 3, we will have 4 stages, each of which will be addressed as a section within our research. The visualization stage will be presented as results, highlighting the clustering applied to the LiDAR data.

3 Point Cloud Preprocessing

In this section, we will delve into the realm of three-dimensional point cloud processing. We will approach this topic through three pivotal subsections: PointCloudData (PCD), VoxelGrid, and Region of Interest (ROI). Each of these subsections plays a vital role in the manipulation and analysis of data sourced from LiDAR sensors and other devices that capture the three-dimensional intricacies of the real world.

3.1 PCD

Initiating the process, we have access to the Point Cloud Data (PCD) Fig. 4 that is read directly from ROS. As mentioned earlier, this PCD is operational within

the vehicle, where Nvidia Jetson acquires this information through ROS. The PCD is delivered in its original format, implying that the LiDAR driver directly publishes the /points_raw topic in ROS.

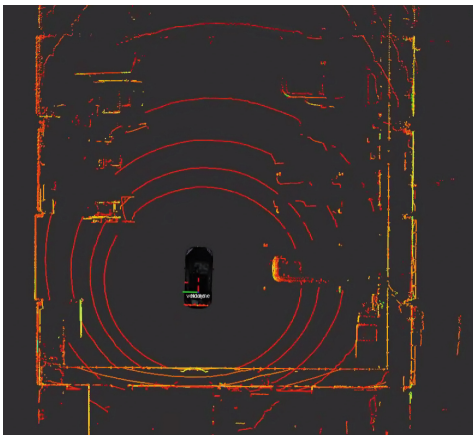

Fig. 4. Point Cloud Data from the Prototype.

3.2 VoxelGrid

We now implement the VoxelGrid technique [5], a crucial element in processing 3D point cloud data, particularly significant for object detection in complex environments. This method reduces the computational load by decreasing data density while maintaining structured environment representation.

VoxelGrid subdivides 3D space into "voxels", akin to 3D prisms. Each voxel contains points within its scope. Assigning points to their respective voxels significantly reduces the point cloud's data volume, streamlining subsequent computations without sacrificing accuracy.

VoxelGrid initially adjusts point density to the desired voxel size, enhancing representation harmony and efficiency (e.g., a value of 0.2). It then aggregates points within each voxel and selects a representative point, further simplifying complexity. This operation effectively minimizes noise, smoothens the point cloud, and highlights crucial features, facilitating tasks like segmentation and object detection.

3.3 Region of Interest (ROI)

The ROI constitutes a fundamental component implemented in this research. This technique aims to exclude specific regions from the point cloud, directing computational efforts solely towards relevant areas of interest. By utilizing predefined coordinates, the ROI is effectively defined as a three-dimensional volume

that encompasses the region in which point cloud processing should be concentrated. The incorporation of an ROI is essential in scenarios where certain parts of the point cloud, such as the vehicle's roof, are irrelevant or contain superfluous information that could hinder subsequent analysis.

For the implementation of this technique, the following parameter values were employed to define the minimum and maximum vectors of the ROI:

- Maximum coordinates in X, Y, Z: (70, 30, 1)
- Minimum coordinates in X, Y, Z: (−30, −30, −2.5)

These parameter values are utilized in this research and effectively delimit the spatial boundaries of the ROI, ensuring that only relevant sections of the point cloud are retained for subsequent processing and analysis.

4 Segmentation

4.1 Random Sample Consensus

In this section, segmentation was carried out-a pivotal process tasked with identifying and isolating a specific region of the point cloud corresponding to the flat surface detected by the LiDAR. Its primary function lies in removing the representation of the ground in the scene. To achieve this, the Random Sample Consensus (RANSAC) model fitting method was employed a robust and widely utilized technique in point cloud data processing.

The RANSAC [2] method commences by detecting the predominant plane within the point cloud. A model fitting algorithm, such as the least squares method, is applied to find the plane equation that best fits a set of nearby points. This plane equation is characterized by its normal vector and constant distance from the origin.

Once the plane is identified through RANSAC, the segmentation process proceeds to divide the point cloud into two distinct portions: the region aligned with the detected plane and the area representing three-dimensional objects and structures within the scene. To achieve this separation, each point in the cloud is evaluated with respect to the plane equation. If the distance between the point and the plane is less than a predefined threshold, it is classified as part of the plane. Otherwise, it is considered a non-planar point.

The outcome of this segmentation is a point cloud divided into two well-defined categories: those points constituting the flat surface and those belonging to the ground region 'Fig. 5'. This segmentation holds significant value in applications such as object detection, as it allows for focused analysis in areas of interest containing pertinent elements and structures.

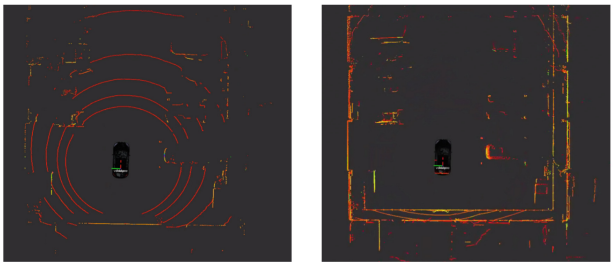

Fig. 5. Left: Point Cloud Data Excluding Ground — Right: Point Cloud Data with Ground

5 Clustering and Tracking

In this section, we present a comprehensive methodology for detecting and tracking obstacles in 3D point clouds obtained from LiDAR sensors [9]. Our approach integrates point clustering, axis-aligned bounding box generation, principal component analysis (PCA)-based bounding box computation, and obstacle tracking to achieve accurate and robust perception in dynamic environments. This methodology is essential for various applications, particularly in the context of autonomous vehicles.

5.1 Euclidean Clustering

The point cloud clustering phase stands as a cornerstone in this research, aiming to group nearby points within the three-dimensional point cloud. This pivotal step relies on calculating the Euclidean distance between individual points, a metric that measures the direct distance between two points in a three-dimensional space. The Euclidean distance is computed using the mathematical formula that takes into account the coordinates of the two points in space and determines the length of the segment connecting them.

To efficiently achieve point clustering, a data structure known as a KD-Tree (K-Dimensional Tree) is employed. A KD-Tree is a hierarchical structure that divides space into multidimensional regions, facilitating rapid and efficient searching for nearby points based on their coordinates [7]. In the context of point clustering, the KD-Tree is utilized to expedite the search process for nearby points, replacing the need to compare each point with all other points in the cloud.

By applying the Euclidean distance alongside the KD-Tree, we are able to identify sets of points that lie within a predefined minimum distance from each other 'Fig. 6'. These sets of nearby points represent distinctive clusters that, in our case, correspond to individual obstacles within the environment. This clustering of affine points lays the foundation for a more in-depth analysis of detected obstacles, enabling the construction of robust and meaningful interpretations of the information captured by the LiDAR sensor.

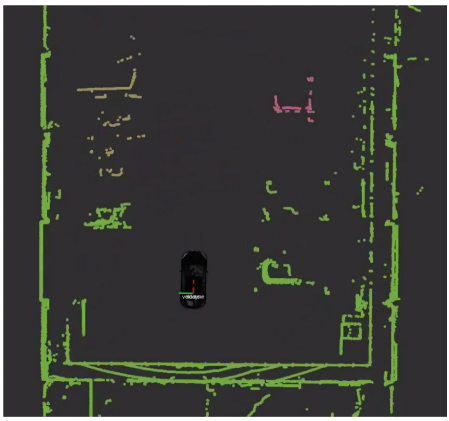

Fig. 6. Clustered Point Cloud Data Representation.

5.2 Obstacle Tracking

Obstacle tracking plays a pivotal role in maintaining perceptual continuity in changing environments. By comparing the bounding boxes of detected obstacles in the current frame to those in the previous frame, it is determined whether they belong to the same moving object. This process enables trajectory estimation and supports motion-sensitive decisions, a critical factor for autonomous planning and navigation. By tracking and anticipating the evolution of obstacles, a comprehensive understanding of environmental dynamics is achieved, enhancing decision-making and safety, especially in applications like autonomous driving. This functionality enhances the system's ability to adapt and respond effectively to evolving scenarios.

6 Results

Following the implementation of the aforementioned methodology, we have achieved the definitive detection of environmental entities through LiDAR sensing. At this stage, we merge the processed environmental data with the previously generated ground points. 'Figure 7' presents a snapshot of the environment captured by a camera, revealing what is perceptible to the prototype's LiDAR. The image showcases the environmental features detected by the LiDAR system.

In 'Fig. 8', we observe the process of bounding box detection for the identified objects. These boxes represent the culmination of the methodology described in this research. We apply the previously detailed methodology to accurately identify and delineate objects. Together, these figures illustrate the efficacy of our methodology in environmental perception, showcasing its ability to identify and characterize objects in three-dimensional environments.

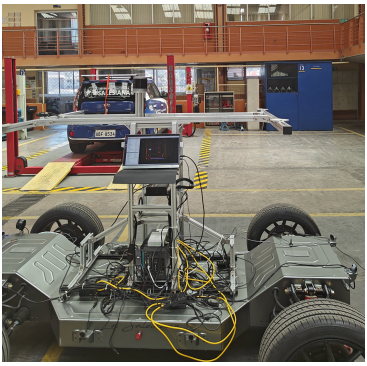

Fig. 7. Clustered Point Cloud Data Representation.

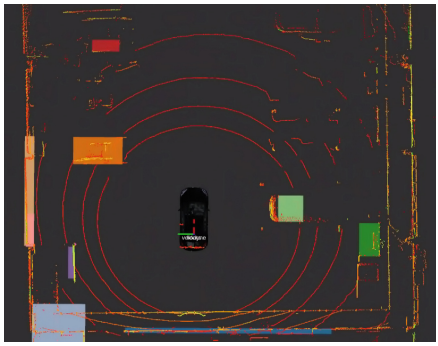

Fig. 8. Clustered Point Cloud Data Representation.

7 Conclusions

In our research, we've analyzed obstacle detection in 3D environments using LiDAR technology. We integrated LiDAR-generated point clouds with environmental data for precise obstacle detection, vital for applications like autonomous driving.

A key aspect of our research is the development of a functional prototype, enabling real-world testing and validation of our methodology. By utilizing embedded systems and the ROS platform, we've shown how emerging technologies enhance environmental perception, particularly in real-time detection algorithms.

Our methodology combines point cloud clustering, bounding box generation, and obstacle tracking, achieving accurate environmental perception in dynamic settings. It is a substantial achievement for ensuring safety and effectiveness in autonomous systems.

Our research introduces an effective obstacle detection and tracking methodology using LiDAR, emphasizing prototype implementation and ROS's role in enhancing environmental perception. This work not only demonstrates efficacy in object identification but also paves the way for advancements in autonomous systems and industrial applications, contributing to improved environmental perception and automation.

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Using Blockchain Technology in Providing Mobile Financial Services to Alleviate Financial Exclusion in South Africa

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Abstract. This paper gives insight into the perceived potential of Blockchain Technology (BCT) in the mobile financial services sector in South Africa. The majority of impoverished individuals do not have banking accounts owing to factors such as paperwork restrictions, high-cost banking fees, and distrust in financial institutions, deceptive adverts, and high interest rates among others. Blockchain technology offers the potential to alleviate poverty-related financial exclusion and to integrate the unbanked individuals into the financial system. Through semi-structured interviews, this study examines the perceived use of Blockchain technology, particularly in the mobile financial services sector. Experts developing mobile services in the banking sector were interviewed. BCT-based financial services may eliminate the need for intermediation, which results in exorbitant costs. BCT may also provide previously unbanked people without proper identification documents with a digital identity. Mobile phones support the installation of blockchain-based applications that enable unbanked individuals with smartphones to have access to the financial system and conduct transactions.

Keywords: Blockchain Technology (BCT) · Mobile Financial Services · Cryptocurrencies · Financial Inclusion · Digital Identity

1 Introduction and Background

Bank accounts are key to everyday economic life in developed countries, but they are far from common in developing countries: only 54% of adults in developing countries have a bank account, compared to 94% in OECD countries [1]. Rather than using banks, individuals save in more informal ways, such as holding cash on hand or purchasing illiquid investments, which can be expensive, risky, or inconvenient [1]. According to the World Bank, about 1.7 billion adults worldwide are unbanked—without a financial institution or mobile money service account – mostly living in developing countries [2].

In the South African context, at least 27% of the population was financially excluded due to a lack of bank accounts [3] and up until the end of the apartheid era in 1994, financial services remained mostly inaccessible to the black population in South Africa.

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Therefore, by default, economically disadvantaged families were excluded [4]. Commercial banks have historically avoided serving low-income earners, micro entrepreneurs, and the poor, mostly due to the high costs involved. Among the reasons for lack of access to financial services for the unbanked and underbanked are the lack of telecommunication facilities in rural areas, the high cost of banking transactions, and individuals who lack identity documents [2].

Blockchain has the potential to fundamentally alter existing financial and economic operating models, resulting in a new wave of technological innovation and industrial transformation within the FinTech industry [5]. These new entrants from the 'fin-tech' start-up world such as Blockchain technology are driving the financial industry toward greater digitalization and efficiency, while promoting bigger transaction volumes and increasing security [6].

Thus, the purpose of this study is to demonstrate the perceived usefulness of Blockchain technology within the mobile financial services industry as a viable solution to the crisis of financial inclusion. Perceived usefulness will be determined through an institutional lens that includes persons and organizations who interact directly with unbanked populations. Although the long-term viability of Blockchain has yet to be established by virtue of it being an emerging technology, early research suggests that it holds great hope and perceived usefulness for increasing vulnerable groups' access to financial services [7].

This study aims to advance research by generating new knowledge and insights about whether or not blockchain technology can be used to facilitate mobile financial transactions to integrate the unbanked into the financial system.

2 Literature Review and Theoretical Framework

2.1 Defining Financial Inclusion

The Banking Association of South Africa has defined "Financial Inclusion" as: "Access and usage of a broad range of affordable, quality financial services and products, in a manner convenient to the financially excluded, unbanked and under-banked; in an appropriate but simple and dignified manner with the requisite consideration to client protection. Accessibility should be accompanied by usage which should be supported through the financial education of clients." [8]. Financial inclusion may also be described simply as the availability of affordable, open, and related financial products to individuals and companies that historically lacked access [9]. Financial inclusion entails expanding the number of (mostly poor) persons, so that they can have access to formal financial service mostly through the opening of official bank accounts thereby contributing to poverty reduction and economic growth [10]. Individuals who were previously financially excluded may now invest in education, save, and start businesses, which adds to poverty reduction and economic growth [10]. As a result, financial inclusion results in economic benefits. It has the potential to benefit disadvantaged and impoverished individuals by increasing their income and employment prospects [11].

2.2 Barriers to Financial Inclusion

The concern persists as to why individuals still remain unbanked. To shed light on why this is, the 2017 Global Findex study asked adults without a financial institution account why they don't have one. The most frequently cited barrier was a lack of sufficient funds. Almost two-thirds of adults without a financial institution account said that they do not have enough funds to open one. Worldwide, 30% of adults without a financial institution account said that they do not need one, making this the second most frequently cited barrier [2]. This means that for those citing a lack of need as one of the factors for not using financial services, others might be receptive to using them if the services are available and important to their lives [2].

Another significant obstacle is cost; 26% indicated that owning and maintaining a banking account is prohibitively costly. Globally, a comparable proportion, 26%, stated that they do not have an account because a family member already does [2]. According to Statistics South Africa's 2017 report, poverty levels in South Africa were extremely high, with around 30.4 million people living in poverty and unable to maintain their bank accounts. Additionally, the poor and low-income earners who work informally do the majority of their daily transactions in cash, as they are not eligible to use formal banking institutions to save and/or budget for future financial obligations [12].

Physical distance is another barrier: adults that do not have a bank account claimed that financial institutions are too far away especially those residing in rural areas. Account ownership is also harmed by documentation requirements. Twenty percent of adults without a financial institution account reported being unable to open one due to a lack of required paperwork [2]. Low-income groups are frequently excluded unwillingly due to the high cost of banking, which is a result of market failures, as well as a lack of required documentation [13].

In certain countries, distrust of the financial system is a stronger barrier than in others. This was cited as a barrier by 16% of adults worldwide who did not have a financial institution account [2]. Numerous factors, including excessive bank fees, high interest rates, deceptive advertisements, and ineffective marketing of financial products, have contributed to the poor and low-income earners' distrust of banks' financial products and services [12]. Additionally, for certain low-income, disadvantaged, and vulnerable households, a lack of general education, more precisely a lack of financial and technical knowledge regarding account ownership, budgeting, saving, and credit management, is a substantial barrier to personal financial stability [14]. Rural/urban migrants and other people unfamiliar with formal banking operations may have a greater need for financial and technical education [14].

2.3 Financial Inclusion in the South African Context

South Africa has made some progress toward increasing financial inclusion. Sadly, statistics indicate a rise in income inequality despite South Africa's remarkable rise and transformation to democracy over the last two decades [15]. Though this issue is largely a legacy of the apartheid period, there has been a shortage of promising public-private efforts since the mid-1990s to begin closing the divide between South Africans who

Table 1. Financial Inclusion in South Africa in Comparison with other Global Nations - % of Population Aged 15+ [15]

Country	Bank Accounts	Formal Savings	Formal Borrowings
South Africa	70%	33%	12%
Sub-Saharan Africa	34%	16%	6%
Eastern Europe & Central Asia	51%	8%	12%
World	62%	27%	11%

are financially included in the country's financial system and those who are financially excluded [15].

Table 1 at first glance suggests that South Africa's financial system is far more inclusive than that of Sub-Saharan Africa, and much more inclusive than that of Eastern Europe and Central Asia, as well as the rest of the world. However, this numerical data masks South Africa's high degree of inequality. In fact, fewer than 30% of low-income adults (the bottom 25%) have a formal bank account, compared to 91% of high-income adults (the richest 25%) [15]. Additionally, residency, age, education level, and gender all play a role in determining account ownership. Additionally, the poor and low-income earners are discouraged from using such services and products as a result of additional strict requirements imposed by banks and similar financial institutions [12]. Exorbitant bank fees and a lack of financial literacy contribute to the financial marginalization of South Africa's poor and low-income earners [12]. Adults with a university degree hold 94% of bank accounts, compared to 43% of those with just a primary education [15]. The issue persists in part because South Africa's banking sector is a heavily concentrated pool of wealth, restricting capital access to the affluent [16].

South Africa's so-called "Big Four" banks have attempted to introduce financial inclusion programs over the years. Nevertheless, they have all failed (Louis and Charter, 2017). For instance, in 2004, the Financial Services Charter (FSC) established a new low-cost bank account (the Mzansi account) and committed to increasing housing and small business lending to low-income earners [15]. And private mobile banking services such as M-Pesa Wallet were introduced in 2010. While these initiatives have been positive, they have fallen short of expectations. The Mzansi account and the M-Pesa wallet have fallen short of their stated purpose of increasing impoverished people's access to financial services in South Africa because they were a subset to traditional banking. [15].

2.4 Challenges Addressed by Blockchain-Based Solutions

Blockchain is often referred to as a distributed or decentralized ledger and operates via a peer-to-peer network [17]. Blockchain maintains a complete, unaltered, and verifiable record of each transaction, ensuring a high level of transparency. If entered, data cannot be deleted. The blockchain maintains an immutable and verifiable database of each and every transaction that has ever occurred [18]. Blockchain incorporates algorithms that enable safe electronic cooperation without relying on a central authority to trust the assets [19]. This incorporates the notion of smart contracts, which refers to blockchains'

capacity to run autonomous scripts that can represent verifiable application logic and assist in automating a system's rule set. The most outstanding feature of Blockchain is that it is a decentralized system with a very lengthy security chain [19].

Blockchain has been implemented in a number of fields including healthcare, transport and middleware [20–22]. One of the primary benefits of blockchain technology is that it eliminates the need for a middleman. Due to the distributed nature of the ledger and its governance by a consensus protocol, third parties are not required to enable transactions [23]. This is a critical factor for lowering transaction costs, which are typically inflated by third-party fees. In comparison, blockchain-based transactions may be executed with extremely minimal transaction fees (Scheutz & Venkatesh, 2020).

Another critical aspect is that blockchain technology significantly decreases the time required to settle transactions. While a typical bank transaction may take several business days to complete, blockchain transactions may complete in seconds, significantly shortening settlement times [24]. This is critical because lengthy settlement delays may deter people from using mobile financial services when an instant money transfer is required. Thus, blockchain technology enables considerable cost and time savings related with mobile financial transactions [25].

A critical concern for unbanked populations is providing lenders with credit histories and guarantees. Due to the immutability of the blockchain, it can serve as a credible record of credit history. If blockchain-based solutions are implemented for all transactions, even informal ones, the history of these transactions may be used to establish credit worthiness [25].

3 Research Methodology

This study adopts an interpretivist research philosophy and is exploratory in nature, meaning that it seeks to gain insight through the use of questions that seek to understand the usefulness of blockchain technology and to elicit information about people's experiences, opinions, and beliefs regarding its use and implementation. A qualitative research approach was followed, using semi-structured interviews. Purposive sampling was used and experts in the financial services industry, currently working with blockchain technologies, were contacted for interviews. In particular, the sample population for this study was not limited to financial institutions, but also included other companies, such as start-ups, that have implemented blockchain technology in their business operations. Individuals who are blockchain enthusiasts and are educated about the distributed ledger and its potential influence on different businesses, notably the financial services industry, may also be included in the population.

Thematic analysis was taken as the most appropriate data analysis technique. Analysis was done after each interview rather than waiting until all interviews are finished before beginning data analysis. This saves time and enables the researcher to rearrange the interview questions and devise a new line of questioning if the one employed following the analysis of the initial interview is unsuitable for the data collection. It also allowed us to assess data saturation. Thematic analysis is the process of identifying themes that emerge as critical to the description of a phenomena. The technique entails "careful reading and re-reading of the data" in order to identify themes. [26] described a theme

as a pattern in data that, at the very least, defines and organizes probable observations and, at the very most, analyses elements of the phenomena. [27] guidelines were used to guide the researcher through their six phases of data analysis in this study.

Prior to beginning the study and data collecting phase, consent from the University's Research Committee was obtained. All ethical protocols were adhered to.

4 Data Analysis and Findings

Due to space limitations, only three major sets of themes will be addressed in this section: usefulness and effectiveness, outcomes and impact, and usability. All participants have used Blockchain in some capacity. Several of the interviewees have employed Blockchain in a variety of areas and in a variety of projects. *"We did a project at AppStrax in 2017, in the Netherlands, where we built a prototype electricity trading platform on a private aetherium network. So, it has a financial element, I think we did integrate into the banks, ABN AMRO at the time, just to convert between euros and our aetherium token."* – INT02. "*We have partnered with a Canadian company who we are doing the business development with where we're trying to come up with a solution in terms of identifying individuals. So, the product is called Digital Identity. Right? So, what it does is, it allows you to store your identity on the blockchain, right? So, it's on hyper nodes."* – INT01.

4.1 Usefulness and Effectiveness

Participants considered blockchain technology to be useful and vital in the field of mobile financial services. The participants cited several reasons to support this statement, including the fact that the technology is cost-effective due to its capacity to eliminate the "middleman," otherwise known as financial intermediaries. Additionally, they mentioned that the technology enables the automation of processes through the use of smart contracts. And that it enables the creation of a digital identity that can be used to transact without the need to present physical documents, and that it fosters trust and enables fast settlements even with people who live abroad. "*So, yeah, it just allows that kind of peer-to-peer automation, whereas previously, you needed quite a few organizations to kind of be part of every single transaction." – INT02. "And then another thing, it also provides easy access to many transfers. And then on top of that, it just assists in, you know, the reduced transaction costs, because it takes out that middlemen, as we said, as well. So transacting, kind of like makes it easier, and much cheaper, cheaper costs than a bank will charge you."* – INT03.

The literature does support the participants' conclusions, particularly in terms of cost effectiveness associated with Blockchain. [28] stated that blockchain technology eliminates financial intermediaries by enabling direct peer-to-peer payments online and self-regulating smart contracts. The most often cited benefits of blockchain technology are cost effectiveness, above-average profits, improved recordkeeping systems, smart digital contracts with universal online identity systems, a secure digital platform, room for innovation, and a lack of governmental constraints [29]. And these are only some

of the perks that contribute to Blockchain's high job relevance, and participants highlighted several of these benefits as some of the distinctive characteristics that distinguish blockchain from other financial technologies.

Some participants noted that Blockchain technology may be used to facilitate remittance payments. The cost of remittances via blockchain is between 2% and 3%, compared to 5% to 20% via third-party facilitation in the traditional banking system, particularly for cross-country payments [29]. While this is a beneficial component of Blockchain technology, it may present some issues, and it is critical to remember that it is still a developing technology, particularly in terms of cryptocurrency payments. As a result, unless governments find a balance of interests and legislation, payments utilizing cryptocurrency may be impossible [29].

4.2 Outcomes and Impact

Participants agreed that Blockchain technology can bear positive results such as Blockchain having the potential to accelerate financial inclusion for the unbanked. This comment was primarily motivated by the characteristics of the technology. The first is that Blockchain enables the creation of digital identities. The following participant elaborates on this point. *"It would increase financial inclusion from an identification perspective. And this is a two-way street, where the regulator's firstly the financial regulators, whoever they are, in whichever country, they need to come to the party, where they actually embrace, adopt and accept digital identities, right away, we can actually allow people to use different means of storing the identities, but also creating different means of locations and addresses."* – INT06.

Currently, the majority of impoverished individuals handle their finances in harmful ways. In place of bank accounts, they usually have cash on hand at home. In the absence of credit and insurance, many people rely on their savings or borrow money from friends and relatives [25]. Savings are more prone to theft or loss; parents cannot guarantee school fees for their children; borrowers in need may be unable to obtain adequate credit from friends or family; and lenders face credit losses. As a result, financial exclusion is a significant economic disadvantage that disproportionately affects already deprived groups [25].

Around 2.4 billion people in the world live in poverty and are unable to answer the basic inquiry "Who are you?" to a government organization or financial institution. And this is not because they do not know who they are, but simply because they are unable to establish their identity via actual proof [30, 31]. Through the creation of digital identities, blockchain technology can simplify and decrease the barrier to entry into the financial system. This would therefore involve a sizable portion of the financially excluded population in the banking system. Blockchain-based identification solutions do not need the storage of your personal information by third-party organizations.

It was also emphasized that Blockchain technology is open, automated, and permissionless. The participants agreed that these attributes make the technology an attractive prospect for promoting financial inclusion. The following participants elaborated on this: *"It's an open and permissionless ledger. The simple fact that I can without, authentication without revealing sensitive parts of my identity simply log on to something. And either swap a token with no friction, or provide the Quiddity and fees as a result of that,*

again, with no friction operation. And in fact, not interacting with any bureaucracy at all right, by literally just calling certain functions on a publicly accessible contracts in a verifiably evident way is absolutely amazing." – INT05. *"It's faster, it's cheaper, and is more efficient, possibly safer too, and cost effective"* – INT04. *"The fact that I can go and I can do a $1 transaction on the slot, and I get treated no differently from somebody who's doing a $1 billion transaction. Which is simply not the case if I'm interacting with Standard bank, Nedbank or any of these kinds of people."* – INT05.

Blockchain is also a defense against discrimination because of its open and permissionless nature; it does not discriminate against anybody; it is quick and inexpensive to use; and you do not have to wait x number of days for your money to reflect in your account. All of these attributes encourage financial freedom and demonstrate that Blockchain can really boost financial inclusion among the unbanked, hence increasing Blockchain's perceived usefulness.

4.3 Usability

With the inclusion of the unbanked, a positive user experience is critical, particularly for residents of rural communities with limited to no digital literacy. The following participant alluded to this issue. *"The onus is on the UX, our UX ecosystem and our UX fraternity in order to ensure that they have a perspective of immersing themselves in the informal sectors, and in the communities of the unbanked so that they, they understand and so that they can translate in, in real terms, and, you know, and as laymen as possible you know, to the different target markets"* – INT04 *"Sometimes when we do development, we develop a product for an individual, but we never speak to that individual. For example, a lot of products in the US, are geared in their minds for Africa, but they have no idea about the challenges in Africa"* – INT04. This emphasizes the need of UX designers creating simple-to-use user interfaces, particularly for the technologically illiterate. Additionally, the user interface must be designed with the purpose of providing a favourable experience for the unbanked. Furthermore, the participant noted how critical it is for the engineers developing and designing these blockchain-based solutions to immerse themselves in their end users, in this case the unbanked, because they are the ones whom the solutions are being developed for.

The literature proposes that engineers use a human-centred approach when building systems, particularly those aimed at low-income populations who lack financial and technology literacy. Human-centred design is defined as an approach to system design and development that focuses on the user experience and applies human factors/ergonomics and usability knowledge and methodologies [32]. Thus, human-centred design differs from many traditional design techniques in that the questions, insights, and actions are focused on the people whom the product, system, or service is designed for [32].

5 Discussion

This section discusses the findings presented above.

5.1 Usefulness and Effectiveness

Blockchain was deemed valuable and relevant by the participants, particularly in the mobile financial services industry. This is due to the appealing qualities of Blockchain, such as the elimination of financial intermediaries, the creation of digital identities, which lowers the barrier to entry into the financial ecosystem, remittances, data privacy, and faster and cheaper settlements. The participants emphasized that these qualities are what fuel analogies between internet adoption and blockchain adoption, since blockchain is a first-of-its-kind financial technology that is particularly distinctive among other financial technologies owing to its open and permissionless nature. However, it was emphasized that blockchain technology is only applicable in a limited number of circumstances. For example, if trust is the primary reason for using blockchain, it may be less beneficial, as blockchain is a complicated technology that makes extensive use of cryptography, mathematics, and statistical algorithms. If the main objective of using Blockchain is to establish trust, companies can embrace simpler, cheaper, and much more efficient alternatives, particularly for small and medium-sized companies.

5.2 Outcomes and Impact

The interviews revealed the possible impact and positive outcomes of Blockchain's results. It was emphasized that using blockchain technology can result in positive outcomes such as increasing or boosting financial inclusion. This assertion is primarily prompted by the fact that Blockchain enables the establishment of digital identities. The unbanked continue to be financially excluded, as financial institutions need physical identification documents to open bank accounts. The potential of blockchain to enable the creation of digital identities lowers the entry barrier to the financial system, allowing an increasing number of individuals to perform financial transactions. Unbanked individuals can engage in financial markets if they have a connected device. Additionally, it was noted that because of the open and permissionless nature of Blockchain, it enables financial inclusion. Additionally, blockchain combats prejudice; it is unbiased and allows anybody, affluent or poor, to join.

5.3 Usability

A positive experience with a system or technology has an effect on how that system or technology is considered to be used. As a result, while designing blockchain-based solutions, a positive user experience is critical. Engineers and user experience designers must use a human-centred approach to interface design because it communicates, empathises with, and prioritizes the user. To create an effective interface, designers must immerse themselves in the life of rural communities. The interface must be straightforward and intuitive to use, while also taking into account the demographics of the individuals for whom it is designed, particularly those who lack financial and technological literacy.

6 Conclusion

The research question for this paper was: "What is the perceived usefulness of blockchain technology within South Africa's mobile financial services industry?" In terms of Blockchain technology, it was determined that it is perceived as highly useful in the mobile financial services industry. Perceived and proposed benefits include the elimination of financial intermediaries, the creation of digital identities that reduce the entry barrier to the financial ecosystem, allows for automation through smart contracts, remittances, data privacy, faster and cheaper settlements, among other things.

However, the technology is not yet mature enough for widespread deployment due to a lack of standards and robust protocols. Historically, the majority of standardization efforts have been focused on the technology itself. There is also no consensus on how blockchain solutions should be constructed, which might have a big impact on the rate of blockchain adoption in South Africa. Additionally, South Africa's high data prices may delay adoption, as the unbanked are predominantly marginalized individuals who lack the means to purchase data bundles frequently enough to conduct mobile financial transactions. Mobile service providers would have to be required to dramatically decrease their pricing in order to attract an increasing number of unbanked persons. Alternatively, low-cost blockchain options such as banking transactions using a USSD number could be investigated. So, BCTs have the potential to significantly speed up South Africa's financial inclusion efforts. However, the technology's issues must be addressed first in order for Blockchain to be mature and suitable enough for adoption.

Given the fact that Blockchain technology is still in its infancy, there are several research gaps. This study will contribute to the body of knowledge by examining how Blockchain might be beneficial in a variety of sectors, including the mobile financial services sector. This study will benefit blockchain enthusiasts as well as anyone with an interest in bitcoin and finance. Additionally, it will benefit firms interested in learning more about blockchain and considering expanding into this field. Additionally, it will seek to improve the government's grasp of blockchain technology in order to facilitate the implementation of blockchain in South Africa. Finally, it will contribute to the amount of academic material presently accessible on Blockchain technology.

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Collaborative Platform for Intelligent Monitoring of Diabetic Foot Patients - Colab4IMDF

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Abstract. This research work aims to set the basis for the development of a multidisciplinary platform designed to assist healthcare professionals, their institutions and more important, diabetic patients to manage diabetic foot syndrome complications. The system's primary function is the automated classification of diabetic foot ulcers (DFU), with the ultimate goal of expediting treatment and improving patient well-being. Given the sporadic nature of diabetic patients' medical consultations, the time gaps between appointments can exacerbate symptoms. To address this issue, the project advocates for sustained communication between physicians and patients, facilitated by the exchange of patient images, thereby reducing the need for frequent in-person visits. This manuscript shows project's initial phase that involves the research and modelling of an architecture that ranges from mHealth to Deep Learning algorithm capable of rapidly and accurately classifying user-submitted images, offering clinical decision support and autonomous identification of potential DFU complications from the patient's perspective.

Keywords: Health Information Systems · Multi-agent · Microservices · Healthcare Standards · mHealth · Diabetic foot wound follow-up

1 Introduction and Contextualisation

The global prevalence of diabetes, coupled with advancements in technology and computer-assisted diagnostics, has engendered novel perspectives and resolutions concerning the realm of mobile health and telemedicine applications. Diabetic patients, given their imperative daily requirements for monitoring blood sugar levels, dietary regimen, and medication adherence, constitute a specific demographic targeted by these emerging innovations, all with the overarching aim of enhancing their long-term well-being [10]. Recent scholarly literature pertaining to the care of Diabetic Foot Ulcers (DFU) has exhibited a diverse array of strategies regarding self-monitoring and clinical decision support systems [14]. One

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exemplar in this domain is a mobile application, denoted as Shenoy et al. [17], meticulously crafted to support diabetic patients in their pursuit of improved DFU symptom management. This application incorporates sophisticated computer vision techniques to meticulously track alterations in ulcer dimensions and the progression of healing. Following the prevailing trend in contemporary literature, Shenoy et al. [17] harnesses Convolutional Neural Networks (CNN) for the classification of DFU images. The use of Artificial Intelligence (AI) models has increasingly overshadowed conventional machine learning methods in image classification, owing to superior comparative outcomes. Additionally, this endeavour posits a proof-of-concept for a fully functional architecture of a mobile application endowed with the capability to expeditiously assess and classify user-submitted images. The ever-growing interest in the development of AI models for DFU segmentation and classification has been stoked in recent years, partly due to initiatives like the DFUC and FuSeg challenges, which confer recognition upon the most adept AI models and computer vision solutions pertaining to automated DFU detection. These challenges afford valuable insights into the state-of-the-art technologies employed and the overarching methodologies deployed to surmount the intricacies intrinsic to model training [6].

The process of training Neural Networks necessitates a substantial volume of input data to achieve desired outcomes. Regrettably, extant DFU datasets often fail to meet the prerequisites for autonomous Neural Network training. Consequently, certain strategies are employed to circumvent the spectre of model overfitting. Data Augmentation techniques offer a means of artificially enlarging the dataset by generating novel images through the application of operations such as cropping, rotation and scaling to extant dataset entries [21]. Transfer Learning, on the other hand, leverages pre-trained networks to circumvent the need for a prodigious dataset dimension for training purposes. This technique is particularly efficacious in feature extraction and can be adapted to fine-tune networks for the more specific objective of segmenting medical images [9]. Image registration, an optimisation process facilitating geometric synchronisation among two or more images, empowers the amalgamation of heterogeneous datasets and mitigates the influence of extraneous factors tied to image acquisition during the training process [11]. Recently devised algorithms in this domain have demonstrated promising results in binary classification tasks, distinguishing between normal and abnormal conditions, as well as in the segmentation of ulcerous regions [18]. However, it is worth noting that only a limited number of these algorithms have endeavoured to comprehensively address the entire classification system. Alternative approaches to DFU prevention involve the utilisation of thermographic imagery for the early detection of symptoms and the attenuation of disease progression. The discerned correlation between cutaneous thermal information and diabetic foot syndrome has proven to be advantageous, although it necessitates the availability of requisite hardware for implementation.

The primary objective of this project entails the development of a platform entitle Colab4IMDF - Collaborative platform for the intelligent monitoring of patients with diabetic foot ulcers. This platform comprises the capacity to assist

healthcare institutions and patients in managing complications associated with diabetic foot syndrome. The automated categorisation of DFU is intended to expedite treatment processes and, in turn, enhance the well-being of patients. Considering that diabetic patients typically undergo medical consultations for follow-up at intervals ranging from one to four times per year, the interim periods between appointments may prove detrimental for the exacerbation of symptoms. Conversely, establishing a continuous means of communication between physicians and patients, including the exchange of patient images, can contribute to a reduction in the necessity for face-to-face encounters between the two parties.

2 Background

The exponential growth of clinical data in recent years has highlighted the imperative need for its systematic organisation, enabling automation, collection, and analysis when necessary. The Electronic Health Record (EHR) system emerges as a pivotal solution, serving as a comprehensive repository for data collection, organisation, analysis, and presentation [12]. Its primary objective is to distil complex clinical information into an intelligible and accessible format for users, thus forming the cornerstone for effective management of a myriad of information types, notably encompassing the patient's medical history [16].

In line with international collaborative efforts, various non-profit organizations, including CEN, HL7, ISO, and the OpenEHR Foundation, have ardently pursued the development of standards and guidelines that define the EHR as one or more open-access information repositories within different Health Information Systems (HIS). Their overarching goal is to facilitate the seamless exchange, integration, and retrieval of electronic health information on a global scale [3,15]. Importantly, these EHR standards are designed to exhibit flexibility in data structures, accommodating the integration of new, clinically relevant information. They establish generic data models that can be linked to specific clinical concepts and information structures. Additionally, these standards are geared towards ensuring the comprehensive representation of the clinical context, including participants and locations associated with clinical activities. Such contextual information plays a pivotal role in interpreting clinical data within the EHR, further augmented by data elements necessary to support audit and control functions [3].

In the realm of medical informatics, the advent of mobile and wireless technology has propelled mHealth (mobile health) to the forefront, representing one of the fastest evolving domains. It has demonstrated remarkable potential in enhancing healthcare services, outcomes, and research, with particular emphasis on its utility in the developing world [1]. The global proliferation of mobile devices, evidenced by the ever-increasing number of mobile phone users worldwide, underscores mHealth's significance. It presents an enticing solution for overcoming existing healthcare barriers, particularly in underserved areas such as rural regions, thereby improving medical accessibility [8]. Furthermore, the adoption of mHealth has the potential to bolster the ageing population's well-being, although its acceptance among elderly individuals remains a subject of

ongoing research [8]. The convergence of the worldwide diabetes epidemic, technological advancements, and computer-aided diagnosis has ushered in innovative perspectives to assist in the segmentation and classification of DFUs. In recent years, machine learning and data mining techniques have gained traction in healthcare. Moreover, deep learning algorithms, in particular, have emerged as a transformation force, exhibiting exponential growth and promising results in research interest since early 2019. Convolutional Neural Networks (CNNs), a subset of deep learning, have become the focal point in the automatic diagnosis of DFUs. Recent research has advanced along three key avenues: wound segmentation, classification algorithms, and architectural design for DFU-related applications [20]. Prominent among these studies like Chuanbo et al. [20], which propose architectures based on MobileNetV2 and MobileNet Convolutional Neural Networks for wound segmentation, using depth-wise separable convolutional layers to significantly reduce computational costs while maintaining performance. Mahbod and colleagues employ Encoder-Decoder-based CNN models, achieving state-of-the-art scores in wound region mapping [13]. Notably, Goyal et al. [6] introduces a binary classification method for DFU segmentation with an impressive Area Under Curve (AUC) performance of 96%. Additionally, Goyal et al. [6], offers valuable insights into an architecture for a comprehensive mobile platform, encompassing a web application and a dedicated server for image processing and classification, thus advancing the concept of telemedicine applications in this domain. Furthermore, the development of a Multi-Label CNN Ensemble has enabled the classification of various DFU-related complications, such as infections and exudate [17]. In this context, this work aspires to leverage the rich landscape of EHR standards, the transformative potential of mHealth, and the cutting-edge capabilities of machine and deep learning algorithms. By amalgamating these perspectives, Colab4IMDF aims to furnish a robust decision support system for diabetic foot ulcer management and follow-up, thereby addressing the multifaceted challenges in this critical healthcare domain.

3 Intelligent Systems Approach

Considering the expected outcome of this project and the main contributions that are being made in this domain, it is essential to adopt several state of the art techniques joint with healthcare standards. As stated in a previous work [2], the adopted approach is a mix between multi-agents and microservices to help overcome most of the challenges that arise from the build up of this architecture. In fact, this approach can lead not only to better user experience, but also increase system availability, but more importantly reduce medical errors and improve the relationship between the medical staff and the patient, bringing better outcomes to the patient with diabetic foot follow-up.

3.1 Health Information Systems

In this section the most relevant concepts in the HIS area are described. Firstly the concept of mHealth and the EHR standards, specifically OpenEHR.

mHealth. The utilization of mmHealth has emerged as a prominent and influential feature in the realm of patient follow-up within modern healthcare. The proliferation of mHealth technology, including mobile applications and wearable devices, has ushered in a new era marked by improved accessibility and convenience for persons in need of healthcare services. These technologies empower individuals to actively participate in their healthcare journey by providing them with a diverse range of resources that can be quickly accessed through their mobile phones or wearable devices. mHealth plays a pivotal role in aiding the real-time monitoring of health issues, hence enabling the continuous collection and analysis of data. The implementation of this approach fosters a heightened perception of self-efficacy and responsibility within individuals seeking medical treatment, so augmenting the overall standard of post-treatment support. Additionally, the utilisation of mHealth technology enables the provision of remote consultations, hence eliminating the need for patients to personally attend healthcare establishments. This is particularly relevant for those with chronic ailments necessitating frequent monitoring and follow-up appointments. mHealth has been found to enhance efficiency within healthcare facilities by alleviating the resource burden, hence optimising cost-effectiveness. In summary, the incorporation of mHealth makes follow-up care more easy, efficient, and focused on the needs of the patient.

EHR Standards. The significance of implementing and following EHR standards, such as openEHR, is crucial in contemporary healthcare due to various compelling factors. First and foremost, these standards serve to enhance interoperability, guaranteeing the smooth transmission of health information across various healthcare systems and providers. The integration of systems and technologies to achieve interoperability not only contributes to the improvement of patient care through facilitating comprehensive access to a patient's medical history, but also mitigates the repetition of tests and procedures, ultimately resulting in financial efficiencies. Furthermore, it is important to note that EHR standards, such as openEHR, place a significant emphasis on ensuring the integrity and quality of data. The establishment of standardised data models and terminologies serves to maintain uniformity in the documentation and analysis of patient data, hence reducing the potential for inaccuracies in the process of diagnosing and treating patients. Moreover, these standards assume a crucial function in promoting patient engagement by facilitating patients' ability to get and comprehend their medical data. This, in turn, cultivates a sense of responsibility and active participation in making informed healthcare choices. Finally, EHR standards serve to foster innovation and enhance adaptability within the realm of healthcare technology. The promotion of modular and interoperable EHR systems is advocated, facilitating healthcare organisations in effectively adjusting to changing clinical and technology demands. In summary, it can be argued that standards such as openEHR play a vital role in the attainment of objectives such as enhanced patient care, decreased healthcare expenditures, greater data precision, more patient involvement, and advancements in healthcare provision.

3.2 Multi-Agent Systems

Multi-Agent Systems (MAS) represent a category of AI systems that employ multiple intelligent agents collaborating to achieve a shared objective. Each agent is a software entity endowed with the capability to perceive its environment, deliberate on its actions, and engage with other agents to plan their activities. The core concept behind MAS is to model intricate systems as a collection of self-governing agents that interact with each other and their surroundings. When constructing a multi-agent system, specific high-level abstractions are often employed. Agents, for instance, are independent entities with distinct realms of control situated within environments where they partake in social interactions. These agents possess the capacity to observe and use their surroundings and available resources. Interactions between agents and other resources are defined by functionalities that can be constrained and further specified by organisational rules[4]. Nevertheless, MAS pose certain challenges. When dealing with conflicting objectives or perspectives, coordinating actions among multiple actors can become intricate and demanding. Additionally, developers working with MAS are required to possess a heightened level of expertise as these systems demand familiarity with technologies such as distributed systems and agent-based modelling. In summary, Multi-Agent Systems provide an effective approach to simulate complex systems and enhance their behavior. Their suitability depends on specific use cases and project objectives, but they have gained significant attention recently as a means to enhance coordination and efficiency across various industries[5].

3.3 Microservices

Microservice architecture, in the realm of software development, refers to the approach of designing smaller, modular services that can be created, deployed, and scaled independently. This architectural paradigm emphasises the division of complex applications into a collection of discrete microservices. Each of these microservices operates autonomously, managing its own processes and interacting with other microservices via simple protocols[7]. The primary advantage of adopting a microservice architecture lies in its capacity to enhance flexibility, agility, and scalability. By decomposing an application into loosely coupled, independently deployable services, developers can work on individual components without disrupting the entire application. This enables rapid development, testing, and deployment of new features[19]. Furthermore, microservices offer improved fault tolerance, as a failure in one microservice typically does not propagate throughout the system. Horizontal scaling, achieved by adding more instances of specific services, facilitates the handling of high traffic loads. However, microservice architecture presents certain challenges. It demands heightened coordination and communication between microservices, necessitating additional infrastructure for fault tolerance, load balancing, and service discovery. Developers must possess a deep understanding of related technologies such as distributed systems and message queues.

4 Colab4IMDF Architecture

This architecture is based on Multi-Agent Microservices [2], which leverages the use of both the Microservice architecture and Multi-Agent Systems, based into separate Docker containers, for easy deployment and fault-tolerance. The proposed architectural framework facilitates the exposition of the capabilities inherent to Intelligent Agents through RESTful APIs. This has a profound influence on the perception and implementation of Multi-Agent Systems (MAS), rendering it more convenient to assimilate agile development methodologies and to effectuate alterations in the way agents are accessed and deployed. The consequence of these adaptations is the realisation of systems characterised by heightened expeditiousness and enhanced cognitive capabilities. The following Fig. 1 represents the components in the system and how they connect with each other.

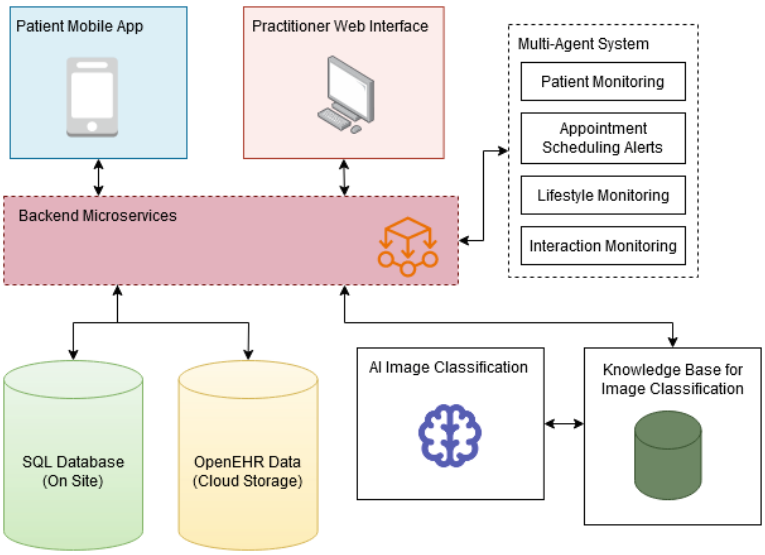

Fig. 1. Proposed architecture

The components depicted in Fig. 1 are described as follows:

- Patient Mobile Application: This mobile application will allow patients to regularly submit images of their plantar foot regions for classification and storage. Based on these images, alerts may be generated regarding the need for medical intervention;
- Practitioner Web Application: Through their designed web UI, practitioners will be able to access patient information as well as review submitted images;
- Backend Server: Cluster of microservices responsible for managing communication between components and logic operations;

- Multi-Agent System: This system is designed to keep track of the information in the platform and generate relevant alerts based on specific triggers across the entire implementation;
- Local Database: Local Healthcare environment databases for personal patient information storage;
- OpenEHR Database: Storage for all components generated through OpenEHR;
- AI Image Classification: AI model for image DFU classification in images of feet plantar areas.

4.1 Main Contributions

As previously demonstrated a complete architecture was designed during this work. This architecture comprises the main topics that we consider to be of most importance to unveil the problem in our hands. Therefore, an approach to mHealth, where patients are taken into consideration and made part of the solution is used. This can ensure patients are committed with the treatment and the mobile app should be precious in order to establish a clean communication path between the several parts of the system. Consequently, this approach can smooth the physicians tasks, since this could lead to better follow-up with less human intervention and a more automatic case segmentation, by prioritising which patients need the attention in the less amount of time[17]. This study emphasises the significant impact of artificial intelligence, namely CNNs, on transforming the care of DFUs. The research illustrates the proactive management of health for individuals with diabetes through the utilisation of mobile applications powered by AI for monitoring DFU. This contribution facilitates the use of more effective and precise monitoring techniques for DFUs, which allows for the early identification of problems and prompt therapies. Consequently, this advancement leads to enhanced patient outcomes and alleviates the strain on healthcare systems.

5 Conclusions and Future Work

In summary, the use of mhealth and telemedicine applications has brought about a significant transformation in the realm of diabetes care, encompassing advancements in technology and telemedicine. Diabetic individuals, who are required to regularly monitor their blood glucose levels, adhere to specific dietary regimens, and effectively control their medication intake, represent a population of interest for long-term enhancements in overall health and wellness. The present study investigated recent developments in the management of DFUs, with a specific emphasis on the potential enhancements in patient care through the use of AI. This study showcases the utilisation of mobile applications to illustrate the role of AI, specifically CNNs, in assisting individuals with diabetes in monitoring and effectively managing DFUs. These applications offer sophisticated symptom monitoring and serve as a demonstration of the feasibility of mobile systems

capable of analysing and recognising images submitted by users. Colab4IMDF is a collaborative system, which exhibit intelligent capabilities in the monitoring of patients with diabetic foot ulcers. The implementation of automated categorisation of DFU, the acceleration of therapy, and the facilitation of ongoing communication between healthcare providers and patients have the potential to revolutionise the management of diabetic foot syndrome in healthcare institutions and among patients. The utilisation of telemedicine and image exchange has the potential to mitigate the need for in-person appointments and enhance the quality of care by expeditiously addressing symptoms, in order to enhance the quality of life for individuals with diabetes and facilitate effective care of diabetic foot ulcers.

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Immersive Shopping Experiences: The Role of Augmented Reality in E-Commerce

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Abstract. Augmented Reality (AR) is a technology that is emerging in the mobile world, more specifically on smartphones. In this sense, new mobile devices have been launched and several studies on this technology already exist. However, regarding the current era, it will still be necessary to determine the main difficulties and challenges of this technology in electronic commerce. This article aims to investigate and identify in studies with a high impact factor in the literature what the next steps could be as well as factors to mitigate difficulties in the future.

Keywords: Augmented Reality · E-Commerce · M-Commerce

1 Introduction

Augmented reality (AR) has become a more evolved technology day by day. With the development of industry 5.0, AR and VR are used to improve employee training, improve equipment maintenance and allow workers to access real-time contextual information while carrying out their tasks. Consequently, when discussing the subject of AR, one of the topics that stands out is electronic commerce [1]. This is because the digital era has brought with it a consumption scenario deeply influenced by the ease of access to the internet, the wide range of products and the convenience of online shopping. However, when talking about virtual shopping, one of the limitations that has always existed was the lack of a tangible and sensorial experience when purchasing, which is quite common when purchasing something in physical stores [2]. AR emerges as a response to this challenge, by fusing virtual and physical elements in a cohesive way, providing consumers with the opportunity to visualize products in a three-dimensional way, interact with them in simulated environments, and ultimately, make more informed and informed purchasing decisions [3] confident. However, not everything is so perfect, as there are still many improvements to be made when purchasing with this type of technology, namely User Experience (UX), related, for example, to problems such as delays in loading 3D mockups, the lack of precision or complicated graphical interface for its use. Other common problems are privacy and

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security, connectivity problems, complexity and development and implementation costs [4,5]. Therefore, some questions arise: **Q1** How are advances being made in this type of e-commerce technologies and what types of solutions are being presented to these problems? **Q2** Knowing that this is an emerging area, will there be interest on the part of researchers in researching AR technology for e-commerce, as well as in Quartile Q2 and Q1 journals in publishing this type of subject? In this sense, with this work, the authors aim to present some studies to try to understand what advances have been made on this topic and, if any, what are the solutions to mitigate this type of problems. They also aim to analyze the interest of journals in the Q1 and Q2 quartiles in publishing on this type of topic.

2 Methodology and Article Selection

Methodology plays a key role in structuring and conducting a comprehensive and meaningful literature review. In this section, the authors will outline a rigorous process by which the sources of information that make up this study were identified, selected and evaluated. The methodology adopted aims to ensure the reliability, validity and impartiality of this review, providing readers with a clear understanding of how the information was obtained and analyzed.

The methodological approach presented here is based on established guidelines for academic literature reviews and is designed to enable investigation into the topic of immersive shopping experiences using AR in the context of e-commerce. In order to provide a comprehensive overview of recent research and developments in this field, the authors followed a series of steps that will be described in detail below.

First, we began by establishing specific search criteria to identify the most relevant sources and then, careful searches were carried out in an academic database with reliable sources, covering a period of time over the last 5 years. Each selected source was subjected to a critical analysis, evaluating its quality, relevance and contribution to the understanding of the topic in question. Through this approach, the authors attempted to consolidate and synthesize information in an impartial and balanced way.

By adopting this methodology, the objective of this study was to provide readers with a solid, abbreviated and informed literature review on immersive shopping experiences in the AR era in the context of e-commerce, highlighting studies, challenges and significant advances in this area. This section will provide a transparent view of the research process, allowing readers to understand the basis on which this study was built, and thus establish a critical appreciation of the knowledge presented in subsequent sections of this same work.

In previous literature reviews the authors used PRISMA[1], "Preferred Items for Reporting Systematic Reviews and Meta-Analyses", to select the most relevant. However, this time we used another methodology with the purpose of obtaining a more cohesive literature for this article.

[1] http://www.prisma-statement.org.

The search was carried out on September 1, 2023 in the repository, SCOPUS. The authors chose this repository because it is one of the largest and most respected repositories of academic and scientific bibliographic databases in the world. SCOPUS is widely used by researchers, academic institutions, publishers and science professionals in order to access information about scientific articles, conferences and books from different scientific and academic areas.

The following keywords were used in this research:

- Augmented Reality
- E-Commerce
- M-Commerce

It should be noted that from the initial research, with just the keywords and over the last 5 years, 62 documents were generated, and after applying the exclusion criteria of only journals and in the English language, a total of 23 documents were created for analysis.

A first analysis was to verify results first determined by the initial research, where in a total of 63 documents it can be seen that from 2019 to 2020 the same number of articles were found, but from 2020 to 2022 the number of documents grew steadily, decreasing in the year 2023 as can be seen in the Fig. 1.

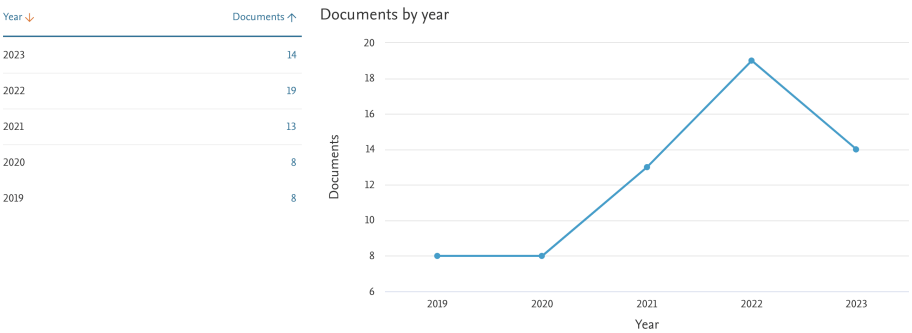

Fig. 1. Evolution Chart of AR Publications in E-Commerce and M-Commerce Scopus (2020)

The search keyword created in SCOPUS is presented below:

```
( KEY ( "augmented reality" ) AND KEY ( "m-commerce" ) OR KEY
( "e-commerce" ) ) AND PUBYEAR > 2018 AND PUBYEAR < 2024
AND ( LIMIT-TO ( LANGUAGE , "English" ) ) AND ( LIMIT-TO (
SRCTYPE , "j" ) )
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In this sense, the results were placed in an annotated bibliography and serialized after an analysis of all 23 articles. Consequently, 12 were excluded as they

were not relevant to the study, leaving 11 documents directly relevant to the study theme.

3 Discussion of Results

This section aims to present the analysis of the articles that the authors considered relevant to the study in order to demonstrate what is being studied and analyzed.

3.1 Analysis of Articles Resulting from the Selection

Kowalczuk et al. address the relative advantage of AR on how products are presented on the web. Using the IKEA Place APP, they developed a model capable of responding to consumer responses and, in this sense, compared consumer reactions between IKEA Place and the IKEA mobile website on smartphones. The Fig. 2 demonstrates both. Kowalczuk et al. concluded that IKEA Place outperforms the IKEA mobile website in product presentation. As an improvement, they denote that interactivity must be increased for purchase intention to be higher [6].

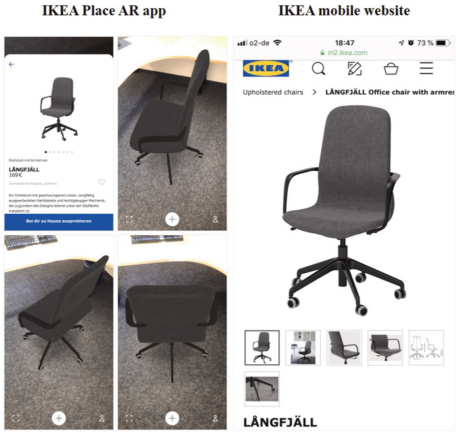

Fig. 2. Comparison figure between the IKEA Place APP and the IKEA mobile website Kowalczuk et al. [6]

When it comes to AR, one of the factors that stands out is the visual quality of the 3D elements. In this sense David et al. carried out a study involving 257 consumers, where they report that visual quality is an increasingly emerging element with regard to behavioral intention in online shopping. In this sense, they tested a model that demonstrates the influence of visual and service quality on consumer satisfaction in relation to a given application and the influence of

consumer satisfaction on recommendation intention in a mixed context (AR and Non-AR). In this study there were 2 groups, one was invited to use a mobile app with e-commerce using AR and the other searched for a product using an online store for mobile devices. It is concluded that the analyzed model has superior explanatory power when applied to a context using AR [7].

One of the questions that usually arises is the risk of adopting AR in E-Commerce. Nugroho and Wang address the Push Pull Mooring Theory, which explains why people change technology and what the result of this migration is, but ignores the risk factors that occur during this process. Nugroho and Wang try to understand this theory related to AR in the purchase of cosmetics and concluded that it is essential to have clear information about product materials and product quality [8].

Lavoye et al. the background and results of the personalized self-exploratory experience central to Virtual Try On applications still little is known or there are no relevant results. In this sense, the authors carried out a test on 254 participants in order for them to virtually try on sunglasses or lipstick and, subsequently, answer a questionnaire. As a result, the authors concluded that Virtual Try On applications through AR have a positive effect on self-explored engagement [9].

Huang et al. carried out a study that through an AR application you can see yourself (as if it were a mirror) and therefore improve your online shopping experience. To do this, they used an experimental AR system and concluded that both body surveillance and fashion awareness significantly influence the application of AR in the consumer's relationship experience [10].

Uhm et al. wanted to understand how AR affects consumers' purchasing intentions. To do this, they used two theories: the media richness theory and the construction level theory with the aim of testing some hypotheses. They concluded that the perceived diagnosis and purchase intention were higher, and the psychological distance and perceived risks were lower in the group that tried e-commerce with AR, compared to the group that tried traditional e-commerce [11].

Moriuchi et al. carried out a study to try to find out more about the attitude and involvement of consumers of AR applications in e-commerce. In this sense, Moriuchi et al. proposed a model based solely on theory that aims to discover the motivational mechanisms that are necessary to provide involvement and decision-making in this context. As a result, it was concluded that involvement with AR increases the attitude towards a company and consequently again affects the visit to an online store, as well as the purchase intention. On the contrary, technological involvement via chatbot had no impact on consumers' attitude towards a particular company [12].

Goel et al. wanted to understand how consumers buy impulsively, and, to do so, the authors carried out a test with consumers who used AR resources in the *Lenskart* app (an Indian company that develops solutions like this type) and purchased a product at least once in the last two months. As a result, it is concluded that sensory perceptions (except acoustics) influence pleasure and the

specific needs of a place or industry can influence the weight and consequences of each sensation, which results in consumers with low involvement with technology they are less influenced to buy impulsively, even activating the various neuro-sensory senses through [13] technologies.

Manchanda and Deb developed a study that examines the impact of anthropomorphism and AR on consumer attitudes and intentions to adopt m-commerce. In this study, anthropomorphism is related to several benefits and obstacles that could influence both consumers' attitudes and intentions to adopt m-commerce with AR. The results indicate that the anthropomorphization of m-commerce with AR positively affects consumer trust, the perception of innovation and the subjective norms attributed to m-commerce mediated by AR and that there is a positive affect on the attitude towards m-commerce with AR [14].

A study with 549 participants carried out by the authors Gabriel et al. demonstrated the effect of adapting AR to beauty and fashion products with the aim of continuing to make purchases online with AR and concluded that interactivity, novelty, value hedonic and satisfaction significantly affect the intention to continue shopping with this type of technologies [15].

Similar to this work presented here, Riar et al. carried out a literature review using people linked to academia who made purchases via AR technology. With this, the authors wanted to evaluate experience and experimentation in the sense that they are transforming the consumer experience. They concluded that the technological capabilities of AR can support the intention to purchase a product, as well as the reuse of an online shopping application with AR, and its recommendation [16].

4 Conclusions

This chapter will present a brief discussion of the results as well as the limitations and future investigations to be carried out.

4.1 Article Analysis Discussion

Kowalczuk et al. address the superiority of AR in product presentation compared to conventional mobile websites [6]. David et al. highlighted the influence of visual and service quality on consumer satisfaction in AR and non-AR contexts, while Gabriel et al. examined the effect of AR suitability in beauty and fashion products on the intention to continue buy online using AR [7,15]. The results highlighted the positive influence of interactivity, novelty, hedonic value and satisfaction on the intention to continue using AR to buy online. Finally Riar et al. highlighted that AR's technological capabilities positively influence purchase intention, app reuse and recommendation of these technologies [16].

Lavoye et al. analyzed the impact of personalized self-exploratory experiences in AR-based "Virtual Try On" apps. The results indicated that AR increases self-explored involvement, emphasizing the relevance of interactivity in the user experience, although Huang et al. verified that what positively influences the

application of AR in the user experience are body surveillance and fashion consciousness [9,10].

Regarding online shopping Nugroho and Wang explored the risk of adopting AR in e-commerce, applying the Push Pull Mooring Theory and concluded that it is crucial to provide clear information about materials and product quality when incorporating AR into online shopping [8]. Uhm et al. have already investigated how AR affects consumers purchase intentions and concluded that AR reduces psychological distance and perceived risks, increasing purchase intention compared to traditional e-commerce [11]. Riar et al. state that the technological capabilities of AR support purchase intention, the reuse of online shopping applications with AR and the recommendation of these technologies [16]. Goel et al. concluded that sensory perceptions, such as interactivity and hedonism, affect purchase intention, but technological involvement via chatbot has no impact [13]. Manchanda and Deb suggest that the anthropomorphization of AR positively affects consumer trust, the perception of innovation and subjective norms associated with AR-mediated m-commerce [14].

4.2 Authors' Conclusions

This scientific paper explored the implications of Augmented Reality (AR) in e-commerce through a comprehensive analysis of eleven relevant studies. The results and discussions presented by the authors indicate that AR is transforming the online shopping environment, influencing consumer attitudes, purchasing intentions, and the overall consumer experience.

From this review, several significant conclusions emerge. Firstly, AR has proven to be an effective tool for presenting products, as evidenced in studies such as Kowalczuk et al., David et al. and Manchanda and Deb [6,7,14]. AR's ability to deliver interactivity, enhanced visual quality, and hedonic value to consumers has contributed to a more engaging and positive shopping experience.

However, it is essential to recognize that the adoption of AR in e-commerce is not without its challenges. As highlighted by Nugroho and Wang [8], managing the risks associated with adopting this technology, along with transparency in product information, is essential to building consumer trust.

Furthermore, adapting AR to the specific needs of each sector and understanding consumers' preferences and engagement levels, as discussed in Gabriel et al. and Riar et al. [15,16], are critical aspects to maximizing the positive impact of the technology.

As we move into the future, several trends and areas of research stand out. One is the continued evolution of AR technology, with the potential to incorporate anthropomorphic elements, as explored by Manchanda and Deb [14]. This can deepen the emotional connection between consumers and products, contributing to brand loyalty.

Another promising area of research is the in-depth understanding of the consumer experience in AR environments, especially in terms of sensory perceptions,

as highlighted by Goel et al. [13]. Understanding how AR affects impulsive purchasing decisions and how to optimize this experience will be a relevant focus for future investigations.

Ultimately, as AR continues to shape the e-commerce landscape, it is imperative that companies ensure consumer transparency, education, and safety regarding the use of this technology. These factors will play a crucial role in building consumer trust and the successful spread of AR in e-commerce.

Additionally, it should be noted that all documents that were analyzed are from quartile Q1 and Q2, which provides reliability in the information collected and analyzed. Based on what was evidenced, several issues can be seen, namely the fact that the year 2023 has not yet ended and therefore the curve in the graph in Fig. 1 is below the expected standard.

In short, Augmented Reality is redefining the way consumers interact and make purchasing decisions in the online environment. However, continued research and development, along with a consumer-centric approach, will be essential to fully harness the potential of AR in e-commerce and to address emerging challenges. As we delve deeper into this field, we can expect significant innovations and continued evolution in AR-based online shopping strategies.

4.3 Limitations and Future Research

Using only one repository and restricting the search to journals may have limited the scope of some results. However, the authors are aware that the information collected is reliable for the study. To enhance the validity of these findings, it may be more interesting to supplement this study with additional data sources such as Web of Science or Google Scholar.

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A Predictive Model of Early Alerts to Improve the Availability of Internet and Data Service of a Telecommunications Company Through the XGBoost Algorithm

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Abstract. The evolution of information and knowledge technologies has caused disruptive business change and new business models, which are based on agile and secure access to data. Therefore, telecommunications companies need to provide quality services that guarantee continuity, efficiency, and privacy in the transmission of information.

This paper addresses the problem of a national telecommunications company, which has detected low rates of availability and intermittence in the data and internet service of its corporate clients, partly generated by the inadequate management of link monitoring, with alerts and corrective actions, which have caused effects to the company such as loss of customers, fines, increase in operating costs, breach of service agreements, decrease in trust and corporate image, etc. In this virtue, we have proposed a predictive model based on data mining and machine learning techniques, which identifies patterns in the historical information of the network equipment. This model can be used to: predict link behavior, detect outages, generate early warnings, and proactively support the company's decision-making. The CRISP-DM methodology has been used for the development and evaluation of the predictive model XGBoost (evolved technique of Decision Trees) in Python Jupyter Notebook. The results are encouraging with an effectiveness of up to 95.5% prediction.

Keywords: Telecommunication · Network availability · Data Mining · Predictive Model; XGBoost

1 Introduction

Information has become one of the most valuable assets within an organization; therefore, adequate information management is necessary, which guarantees: the availability, confidentiality, privacy, integrity, and authenticity of the data [1]. Telecommunications, together with other components of IT, allow organizations to carry out adequate information management, helping institutions to meet their goals [2].

In Ecuador, both public and private policies and regulations have been established, which help guarantee the continuity and quality of the telecommunications service [3].

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One of the main telecommunications companies in the country incorporates SLAs with its corporate clients that commit the institution to carry out adequate management of the availability of its services. In recent years, the telecommunications company has suffered constant availability problems due to cuts and intermittence of internet and data services, which cause breaches of the SLAs established with its corporate clients; this generates fines, contract terminations, loss of reliability, and decreased corporate image. Currently, the company has implemented a monitoring system and data analysis carried out on the data stored in this system, detected that the behavior of the sensors of the network devices has saturation patterns and trends prior to cuts or loss of service. Therefore, a massive and automatic analysis is required to detect trends that give early warning of possible service outages and allow operational personnel to take proactive actions. The use of Data Mining (DM) and Machine Learning (ML) techniques is proposed.

It is emphasized that there are other related studies that propose ML prediction models, among which stands out is the one proposed by Garima and Rajeev in 2020 [4]. Unlike this one, the present study proposes to develop a predictive model associated with the availability of the service offered by a telecommunications company in Ecuador; through the use of several network sensors (traffic, memory, CPU, ping), and the implementation of the XGBoost algorithm.

2 Theoretical Framework

2.1 Data Mining Techniques

These techniques aim to obtain patterns or models from the treatment of the data collected [5]. According to the objective of data analysis, the techniques are classified into two groups: descriptive (unsupervised) techniques and predictive (supervised) techniques [6]. As for the predictive techniques, they are oriented to estimate or predict output values and are used when the objective results of a data set are known [7]. Supervised learning builds criteria from a set of cases or examples called training sets, whose results are known, in order to determine (predict) the results of new cases in the domain [8]. After making a specific process, it was obtained as a result decision trees allow us to generate a predictive model of dynamic thresholds of network sensors and early warnings; with the purpose of improving the availability indexes of the corporate internet service and data of the telecommunications company.

2.2 XGBoost (Extreme Gradient Boosting)

The XGBoost algorithm is a supervised learning technique (predictive), the result of an evolution of Decision Trees [9]. The "Fig. 1", shows the evolution of the different algorithms up to XGBoost.

Among the main features and advantages of XGBoost is that: Assembly in a sequence of decision trees called CART (Classification and Regression Trees), the trees are added sequentially and learned from the previous trees, correcting the error (descending gradient); allowing its growth and handles large volumes of data [10].

Fig. 1. Evolution of algorithms based on decision trees.

2.3 Methodology CRISP-DM

Cross-Industry Standard Process for Data Mining (CRISP-DM), is a standard methodology, proven in DM projects [11]. The six phases that comprise the CRISP-DM life cycle are: Business Understanding, Data Understanding, Data Preparation, Modeling, Evaluation, Deployment [12].

3 Experimental Setup

To obtain the predictive model of this project, CRISP-DM was used. The main results of each of its phases are detailed below:

3.1 Phase 1. Business Understanding

Determining Business Goals

- Develop a predictive model of dynamic thresholds using network sensors and early warnings, using DM techniques based on device behavior trends; with the purpose of improving the availability indices of the corporate internet service and data of a telecommunications provider company in Ecuador.
- Evaluate the proposed model, through a Benchmark case study, which will improve the levels of performance and availability of services.

Determine DM Goals

- Determine the suitable supervised predictive data mining techniques, which allow forecasting and establishing dynamic thresholds of network sensors.
- Develop a predictive model of dynamic network sensor thresholds, using data mining techniques based on device behavior trends.

3.2 Phase 2. Data Understanding

Initial Data Collection. The operation of the systems and data repositories that the company has for network information is analyzed. It is obtained that the main structures where the necessary information for the DM process is stored are: Network groups, devices, and sensors; Monitoring data; Availability data; Events & Thresholds.

Data Exploration. The exploration of the stored data allows us to discover trends in the information for the DM process. This task is performed through SQL queries to the tables and views of the NMS system, and with the help of visual tools for graphical representation. It has been found that there are 345 active devices (56%) out of a total of 619 devices in the monitoring system, from which information can be obtained for the MD model. Additionally, there are 1,093 million (M) records between March 1 and June 20, 2020, these are distributed by type of sensor, and it is obtained that: the traffic sensor has 4 channels and represents 54% of the total records, followed by the memory sensor with 2 channels that represent 23%, finally there are the Ping and CPU sensors with 1 channel that represents 12% and 11% respectively.

The average daily downtime indicates the percentage of device unavailability and can be interpreted as a value contrary to availability. Therefore, this measure is part of the target variable of the DM predictive model. "Figure 2", presents the downtime measurements (%) between March and June 2020. However, it can be seen that, between March 11 and 20, 2020, there are outliers of unavailability, for this reason, they are discarded for the training of the DM model.

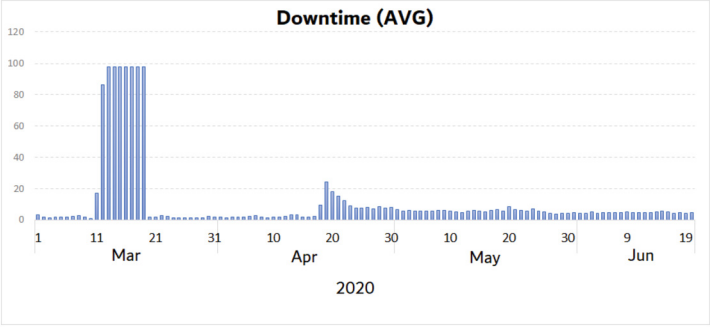

Fig. 2. Daily evolution of the percentage of downtime.

"Figure 3", shows the daily number of events alerted by the NMS system, a total of 50.21 M, which are of different types of impact: minor, warning, and critical. The information can be viewed between the months of March and June of the year 2020. However, there are atypical data in most of the month of March. In meetings held with the technical staff of the telco company, this variation is due to saturation and system load at the start of the Covid-19 pandemic. Therefore, the decision is made to discard the data from March 2020, because this information does not have a normal flow, and can generate a biased DM model with an incorrect prediction percentage.

Data Quality Check. After the exploration was carried out, it is concluded that: The data is complete and stored in a SQL Server 2017 database; the data was found to cover the requirements to obtain the necessary results and meet the objectives of the DM project. The data does not contain errors since it is entered by the NMS software automatically; there are records with null monitoring values, reflecting that there may be losses in monitoring and/or link cuts.

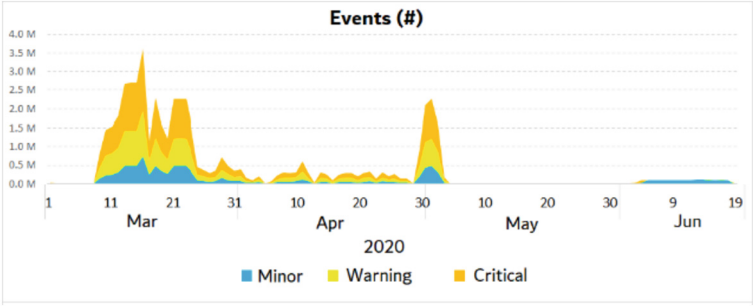

Fig. 3. Daily evolution of events by severity.

In general, with the exploration carried out, it is verified that the data is valid, complete, and without errors for the DM process. Additionally, there is an extensive amount of information with minute monitoring for the generation of tests and evaluation of the model.

3.3 Phase 3. Data Preparation

Data Selection. We proceed to select the relevant data aligned to the achievement of the DM predictive model and its subsequent evaluation. Next, the selection of elements at the record level made is listed:

- Data from groups, devices, and network sensors active in the monitoring system.
- Channel data and monitoring capture carried out between the months of April and June 2020.
- Active Static Threshold Data.
- Data on events and availability that occurred between April and June 2020.

Data Cleaning

Lost Data. There is lost monitoring data from devices that were temporarily inactivated for maintenance reasons or decisions that depended on the client or provider and that were later activated. Additionally, there is historical data that have been moved to other databases to which the author of the project does not have access.

Data Incoherence. Based on the exploration carried out, no inconsistent data has been found, neither in the data related between structures nor in the monitoring measurements.

Data Protection. Due to the confidentiality and security agreements that the telecommunications provider maintains with its customers, the names of groups, devices, and sensors have been changed to generic names.

Data Errors. By using data cleansing techniques provided in the Python language, we proceed with this task.

New Data Construction. To achieve the objectives of DM, we proceed to build tables and views of the database, with the help of these, it is possible to create the table

[MON_MONITOREO_TABLE] which is the main structure and base for the DM process. Additionally, using Python code, the objective variable for the DM predictive model is created, which is called "failure", which is a calculated field, which indicates in a binary way if there is unavailability = 1, or if the availability is normal = 0.

4 Modeling and Results

4.1 Phase 4. Modeling

Selection of Modeling Techniques. After the analysis and investigation carried out through an SMS, it has been determined that the decision trees and the XGBoost algorithm can help to achieve the objectives set out in this study.

Model Generation. The model has been programmed in the Anaconda Distribution Jupyter Notebook IDE (Python), with the use of the libraries, Dask: for parallel processing and XGboost: for the implementation of the selected algorithm.

For the training Data Set (train) and test (test), data has been taken from the devices between April 15 and May 15, 2020, due to the exploratory analysis carried out in Phase 3 of CRISP-DM and corroborated in meetings held with the personnel of the telecommunications company, who indicate that in this period of time, the NMS system is stable. The data set is partitioned, 80% for training (dtrain) and 20% for the test (dtest). The Python XGboost library has been used for the model, which has been calibrated with the following options: **objective: 'binary: logistic'**. Indicates that logistic regression is to be used for binary output probability classification. (1 = no availability, 0 = normal availability); **max_depth: 3**. Indicates the maximum depth of each tree; **min_child_weight: 0.5**. It´s the minimum instance weight sum needed in a child tree.

The selected options and their arguments are based on what is indicated in the XGBoost library web documentation [13]. It is important to know that this calibration has been carried out based on the hardware resources available for the development of the DM project and the author's experience. "Figure 4", presents the Python code for programming and configuring the DM model. The configured parameters (params), the training data set (dtrain) and the number of random forests to be generated internally (num_boost_round = 3) are sent. After the execution, the results will be obtained in the variable called "bst" which is the predictive model already trained, and which will later be evaluated.

```
params = {
            'objective': 'binary:logistic',
            'max_depth': 3,
            'min_child_weight': 0.5,
}
bst = xgboost.train(params, dtrain, num_boost_round=3)
```

Fig. 4. XGBoost model programming and configuration.

4.2 Phase 5. Evaluation

Results Evaluation. To test the quality and validity of the model, ROC – AUC will be used, which is a statistical evaluation metric for binary classification problems [14]. The same one that captures the results of the "bst" model in the "y_pred" variable, which is the collection that contains the prediction results, this is compared with the "y_test" variable, which is the collection of the real results of the test. Subsequently, the rates of false positives (FPR) and true positives (TPR) are calculated. Finally, with these data, the ROC - AUC values are calculated and they are graphed. After executing the model with different groups of devices in the Python Jupyter Notebook tool, the following evidence is found: "Figure 5", presents the results of the ROC Curve and AUC of the different executions carried out. Consequently, it is feasible to improve the results of the model from 0.71 to 0.9550 of AUC, which is interpreted in that the final DM model has an effectiveness of up to 95.5% of prediction.

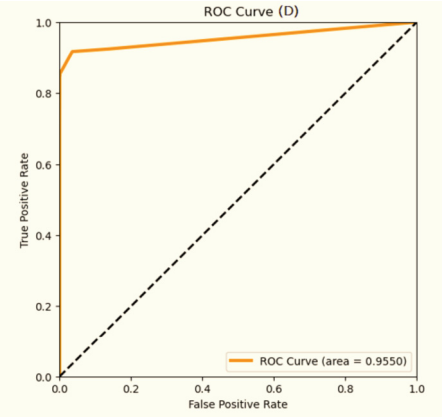

Fig. 5. ROC – AUC results applied to the DM Model.

Review Process. Following the proposed business and data mining objectives, it is essential to have a review process that allows for evaluating and verifying the results, for this a Benchmark comparison will be made through a case study. "Figure 6", presents the process for the review of Benchmark study cases, this is based on the comparison of two clients of the supplier company when applying the DM model in their devices.

In general, the Benchmark method allows the comparison between two similar entities, in this case, the comparison between two clients (A and B) of the telecommunications company. "Table 1", presents a comparison of customer characteristics and the results of applying the prediction model.

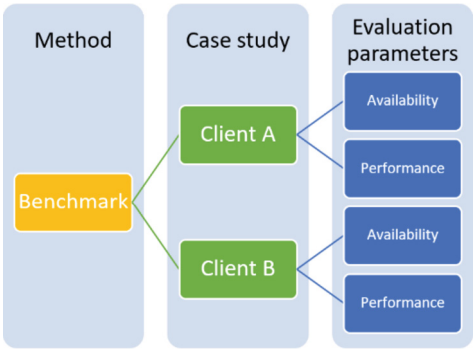

Fig. 6. Review process Benchmark case study.

Table 1. Comparison of client A and client B case studies

Characteristic	Client A	Client B
Company name	E_434320	E_233536
Number of devices	3	3
Starting date	15-04-2020	15-04-2020
Ending date	15-05-2020	15-05-2020
Number of records	430,053	435,479
Null record percentage	2.07%	2.25%
Number of records with failure	8,384	9,227
Percentage of failed records	1.94%	2.11%
ROC – AUC	70.99%	94.00%
Average availability without applying the DM model	98.07%	97.87%
Average availability with DM model application simulation	98.88%	99.74%
Improvement percentage after applying the model	0.81%	1.87%

In the evaluation of the DM model, an estimate of the characteristics has been made, that is, the fields that have the greatest influence within the model are obtained. "Figure 7", presents a comparison of these.

Evaluation Results. In general terms, it is an encouraging percentage since with these values and correct management in decision-making, it can be improved between 0.81% and 1.87%, in terms of its availability.

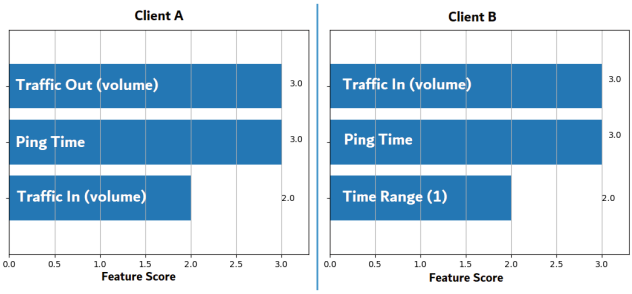

Fig. 7. Comparison of features of importance in the model.

5 Discussion

There are several studies related to the prediction of network traffic, among the main ones analyzed is: The article by Garima and Rajeev in 2020 [4], who generate a prediction model with ML algorithms: Prophet and XGBoost, the results indicate that both models are accurate, however, the latter is more accurate (up to 98.4%) even with fewer data and allows estimating traffic at peak hours; Also, there is the article proposed by Shana B. and others in 2020 [15], This study is based on the estimation of the best route of network traffic, based on the previous observations, to improve the quality of the services, the authors propose and apply the ML algorithms: Random Forest and XGBoost, reaching the maximum precision this latter with a Mean Absolute Percentage Error of up to 5%.

Our work has similarities regarding the use of XGBoost for network traffic prediction with other studies. However, the main difference is to generate early alerts to improve the availability of the service through a Benchmark, covering the reality and data of corporate clients of a telecommunications company in Ecuador. Regarding the results of the prediction model, there is an accuracy of up to 95.5% and the Benchmark that compares the availability of the service presents an improvement of up to 1.87%, this directly impacts compliance with the SLAs; from the company to its customers. As you can see, our work contributes to better organizational efficiency and much more effective decision-making.

6 Conclusions

To carry out this study, the CRISP-DM methodology was used, as well as the ML XGBoost algorithm. The model was trained and tested with historical network monitoring data from corporate clients of a telecommunications company in Ecuador. For this, ROC and AUC were used and evaluated with results of up to 95.5% prediction.

A Benchmark analysis was carried out that simulates the comparison before and after applying the prediction model, detecting possible anomalies and failures in the network, and with adequate support, an improvement in the availability of services between 0.81% and 1.87% can be obtained, allowing the company to comply with the SLAs acquired with its clients.

It should be considered that the prediction model and the Benchmark analysis were carried out based on the data of corporate clients of a telecommunications company in Ecuador. Therefore, its application in other companies in the same industry is not necessarily easily adaptable. However, it can be taken as a basis for future related studies.

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Software and Systems Modeling

Towards Multi-agent Specification of Health Care Systems Using π-Calculus

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Abstract. In this paper, we propose the use of π-calculus, a formal modeling language, for the specification of healthcare systems. π-calculus offers expressive primitives that enable rigorous and correct specification of these complex systems. We have applied π-calculus to specify Multi-Agent Systems (MAS) within the healthcare context and obtained promising results. By leveraging π-calculus, we address the intricate challenges of modeling MAS in healthcare, allowing for precise system descriptions and analysis. Our findings indicate that π-calculus is well-suited for the task of MAS specification in healthcare.

Keywords: Health Care Systems · Multi-Agent Systems · π-Calculus

1 Introduction

Multi-agent systems (MAS) are widely used in daily life performing various tasks visibly and invisibly. Their use is increasing every day in various sectors of the industry ranging from health to manufacturing. Specifying, designing, implementing, and deploying these systems is critical to their success. Most important in these phases is the specification of these systems. Specifying accurately and unambiguously these systems are essential to their success.

There are many general-purpose specification languages like VDM (Jones, 1990) [1, 2], Z [3], and OBJ [4, 5]. However, these languages have not been designed for MAS and hence they fail to achieve the purpose. VDM and Z are model-based approaches on one hand and OBJ is based on an algebraic specification on the other hand lack mechanisms to allow users to specify interactions between agents. Hence, they are unsuitable for MAS specifications. Ideally, what we would like is a specification language that allows its user to express the interaction between the pieces of the system and allow the modelization of concurrency between the pieces of these systems.

In this paper, we advocate the use of π-calculus to specify MAS in the context of healthcare because it includes the necessary expressive primitive power that enables the specification of these systems accurately. π-calculus is a mobile calculus suited for the description of concurrent systems and hence MAS. It is an extension of its predecessor CCS (Calculus of Communicating Systems) [6].

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In MAS peers need to change dynamically the configuration of the communication between agents. Previous models such as Petri nets [7] and CCS lack this essential feature needed between agents. π-calculus embeds this important feature in the calculus.

The structure of this paper is as follows. In the next section, we describe the environment and settings where the proposed usage of the π-calculus is assumed. In Sect. 3, we briefly outline the syntax and operators used from the π-calculus for our purpose, while Sect. 4 shows how we can use the π-calculus for specifying MAS in health care context. Section 5 discusses related work while Sect. 6 argues on the limitations of this work and suggests solutions. Section 7 concludes the paper and outlines further research directions.

2 Environment

It is important to define what an agent is and what MAS is before we can define the environment in which our work can be applied. [8] defined an agent as: "anything that can be viewed as perceiving its environment through sensors and acting upon that environment through actuators." Another definition by [9] is: "an encapsulated computational system that is situated in some environment and this is capable of flexible, autonomous action in that environment in order to meet its design objective."

Multi-Agent System (MAS) is a set of agents that work together to solve complex problems, negotiate, execute trade transactions in an electronic marketplace on behalf of their users, share information with each other, etc.…

We consider an environment in which agents operate as a set of MAS. We have a set of patients that require having certain insurance provider that allow them to visit certain medical care institutions. We have a set of insurance providers that in addition to the duties outlined in the policies have a duty of good faith and fair dealing when handling any transaction. We have a set of brokers that facilitate of the search for a proper insurance provider on behalf of its customers. We have a set of medical health care institutions. Figure 1 below illustrates this scenario.

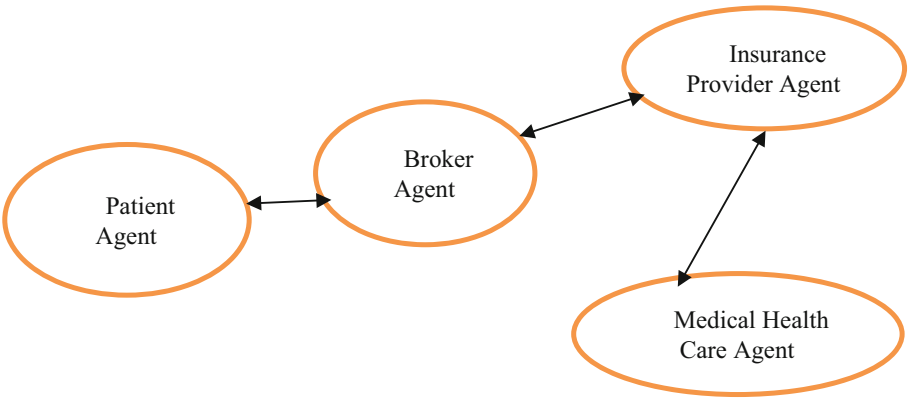

Fig. 1. Medical Health Care Agent System

The patient requests certain services from the broker agent regarding health insurances. The broker agent negotiates with the patient regarding the requirements, policies and cost. Once an agreement has been reached, the broker search for an insurance provider that offer these services with the agreed cost between the patient and the broker. If such insurance provider has been found the deal is made otherwise a new negotiation that takes place between the patient and the broker to rectify the requirements and cost.

3 Pi Calculus

The basic element of the π-calculus is a name [10, 11]. Processes use these names as channels to interact between themselves. A receiving process may use the name to conduct communication with another agent. In this paper, we take the view that an agent is a process. Agents evolve by performing actions. The actions are prefixed to agents. We take from the π-calculus only the following actions, which we believe are sufficient in the specification of MAS:

$$acton := \bar{x}y|x(z)$$

where x, y and z are names that can model an agent or a link between agents.

The remaining actions from π-calculus are the silent action (tau) and the match action which we believe are not relevant in the specification of MAS.

The syntax of the evolvement of agents following the π-calculus style is as follows, using an Extended Backus Naur Form (EBNF) notation [12]:

$$A := M|A|A'|\upsilon zA|!A$$

$$M := 0|actionA|M + M\prime$$

where A, A' are agents and M is a term in the calculus. A brief description of the above grammar is given below.

!A is the replication of the agent A and υz A is the restriction of the name z in A.

action.A: the π action will be executed then the agent A will proceed.

+ is the or operator in the calculus.

It should be noted from the syntax the recursion nature that one can use to model complex systems.

4 Specification

The specification is split into three main processes: the patient agent, the broker agent, and the negotiator agent.

4.1 Patient Agent

```
Patient(γpatient_ask, γpatient_neg, γpatient_recv, requirements, cost) def
  (ν  negotiate, wait, modify_req, receipt)
  (--- Initial phase needs to be transmitted to the
       broker
  (ν pat_ask)
  (  γpatıen_ask <γpat_ask, requirements, cost>.
     γpat_ask(agreement, req_changes).
     ( [agreement = OK]
       wait <requirements, cost>.0
       [agreement # OK]
       negotiate<requirements, cost, changes>.0)
  )
  |
    --- Negotiate phase
    ! γnegotiate(req, cost)
  |
    --- Waiting phase
  ! ( γwait(requirements, cost).
      γpatient_recv(agreement, req_changes).
     ([agreement = OK]
      γ recipt.0
     +
     [agreement # OK]
    γnegotiate(requirements, cost).0)
  |
     ----Final phase
    γfinal_receipt.0
  )
```

4.2 Broker Agent

```
Broker(γpatient_ask, γpatient_neg, γpatient_recv,
          requirements, cost) def
(ν  γverify, γnegotiate)
( γpatient_ask(γpat_ask, req, cost).
  γverify<req, cost>.
 γverify(agreement, req_changes).
γpat_ask<agreement, req_changes>.
([agreement = OK]
  γinvite_insurance (req, cost).0

  +
 [agreement # OK]
    γnegotiate.0)
|
---Negotiate phase
---This phase negotiates with the patient
!( γnegotiate.
  Negotiator(γpatient_neg, γverify) )
|
---Invitation of insurance provider ….
! ( γinvite_insurance_provider<req, cost>.
   γinvite_insurance_provider(agreement, req,
     cost).
   γpatient_recv<agreement, req_changes>.
  ([agreement = OK]
  γfinalise.0
   +
   [agreement # OK]
   γnegotiate.0 )
```

4.3 Negotiator Agent

```
Negotiator(γpatient_neg, γverify) def
(
γpatient_neg(γpat_neg, new_req, new_cost).
 γverify<new_req, new_cost>.
γverify(agreement, suggested_changes).
 γpat_neg<agreement, suggested_changes>.
([agreement = OK ]
  γinvite_insurance_provider<new_req,  new_cost>.0
    +
  [agreement # OK ]
  Negotiator(γpatient_neg, γ verify)  )
)
```

5 Related Work

A good review of the application of modeling in the healthcare can be found in [13]. [14] uses π-calculus to specify a multi agent architecture in the context of manufacture. It shows how π-calculus can be used to model different agents like the customer, the logistics and other entities in a supply chain. Hong Zhou [15] worked on a specification language for agent-oriented software. This specification language is designed for modular and composable specifications for MAS. It is inspired from object-oriented paradigm.

DESIRE [16] conceived a formal specification at the conceptual level. This language is specific, whereas the approach we adopt, using π-calculus, is more abstract and has more expressive power than DESIRE. [17] is a good reference on the specification and verification of MAS.

[18] uses UML statecharts specification for MAS targeted for manufacturing. However, this approach is tailored to one domain, which is a manufacturing. To extrapolate the approach to other domains it needs to be explored.

In the literature, we have not come across many usages of the π-calculus as a vehicle of specification for MAS. For instance, [19] defines a dynamic architecture for MAS using π-calculus whereas [20] uses the π-calculus to verify the service composition in web services.

6 Work Limitation and Suggested Solutions

The π-calculus suffers from certain drawbacks regarding dynamic behaviours of agents i.e. it is not possible to set constraints on the time between communication between agents. In MAS, the response to the requester is vital for its operations. It cannot wait for an unknown time. Leaving this aspect un-specified in a MAS development will be catastrophic to the system to be built.

To solve the above problem, one may recourse to temporal logic [21] or interval temporal logic [22] to resolve the time constraint issue. Temporal logic provides expressive power to refer to the future. It includes the following operators always operator □ and eventually operator ◇. □ p means that p is true now and in the future while ◇ p means that p is true now or eventually will be true in the future. We can apply these operators consecutively to express more complex statements. Interval temporal logic is more suited to be applied with π-calculus as it is designed to express property that needs to be true within an interval.

Hence, there is a need for further research to be done to bridge the gap between π-calculus and temporal logic to be able to correctly specify these systems.

7 Conclusion

In this paper, we have shown how π-calculus can be used to model MAS in the context of health care. π-calculus includes built-in primitive constructs that allow the specifier to express his/her intention quite accurately. We discussed the limitation of this work and suggested solutions that can be a potential venue for further research.

This work holds significance in enhancing the formalization and specification of healthcare systems, ultimately contributing to the development of more reliable and efficient healthcare solutions. The application of π-calculus provides a robust foundation for modeling complex healthcare environments, offering potential benefits in areas such as system design, analysis, and validation. Our results pave the way for further research and practical applications in the healthcare domain, facilitating advancements in healthcare system development and operation.

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SECRET: A New SECurity REquirements SpecificaTion Template

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Abstract. The growing number of software and hardware system attacks has made security a critical factor in their design. To guarantee the safety of the system, security requirements must be established, but this is a difficult task since they are usually expressed in natural language. Researchers have proposed structured natural language templates for specifying security requirements to simplify this process. These templates must consider various security aspects, such as security criteria and mechanisms. This paper introduces the SECurity REquirements specificaTion (SECRET) template, developed through two action research cycles to address these issues. Initially, the SECRET template was created and tested by identifying and resolving problems in defining security requirements. Then, the SECRET template was applied to a use case, and it was concluded that all security requirements were correctly specified.

Keywords: Security requirement · Security requirements engineering · Natural Language · Template

1 Introduction

The past few years have seen a sharp rise in security threats to software and hardware systems, making security a critical factor to consider during the development process, beginning with the definition of requirements. However, creating accurate, simple, and non-complex security requirements is a time-consuming and laborious task. To address this issue, guides have been created to help security requirements engineers define their requirements.

Natural language (NL) is widely used for requirements elicitation and documentation due to its accessibility and minimal training requirements [3]. However, NL-based requirements often suffer from ambiguity, lack of clarity, inconsistency, incompleteness, vagueness, complexity, duplication, verbosity, implementation challenges, and untestability [12]. To address some of these problems, semi-structured natural language in templates has been proposed. Templates

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help structure requirements while retaining the advantages of NL, reducing early-stage defects in the development process. Adapting templates to the security domain requires consideration of specific security aspects, including security criteria and mechanisms. Previous work identified deficiencies in existing requirement templates [7], such as missing quantities, non-verifiable non-functional requirements, and insufficient specificity [14]. Other templates and libraries have been proposed to assist engineers in writing security requirements [6,9]. However, these approaches had limited coverage of security aspects.

This paper introduces SECRET (SECurity REquirements specificaTion), a security requirements template building upon Mazo *et al.*'s template [14] while considering application and domain requirements, including those crucial for product lines [13] and self-adaptive systems [19]. SECRET provides structured guidance for specifying functional, non-functional, and security requirements. It seeks to answer two key research questions: *What should a well-structured security requirements template include?* and *How should security requirements engineers utilize this template?* The proposed template aims to (i) establish a guided process for specifying these requirements, (ii) distinguish problem and solution spaces, and (iii) differentiate domain from application requirements.

The rest of the paper is structured as follows: Sect. 2 explores templates and guidelines. Section 3 discusses the research method. Section 4 reports issues identified using the Mazo *et al.*'s template. Section 5 explains the SECRET template for security requirements specification. Section 6 presents the SECRET template evaluation. Finally, Sect. 7 covers the conclusions and future work.

2 Baseline and Related Work

Controlled natural language: Structured requirements often use controlled natural languages like Attempto Controlled English (ACE) [20], which enables clear domain-specific expressions. However, ACE does not cover security or self-adaptive systems. In contrast, Gellish, an application-independent language, facilitates system customization and data integration but lacks support for security criteria and mechanisms [17]. **Guidelines and templates:** Various works provide templates and guidelines for specifying requirements. EARS by Mavin *et al.* simplifies requirements into five templates but does not address security or domain-specific requirements, focusing on system requirements [12]. Mahmud *et al.* offer a structured ReSA language toolchain for more precise requirements but lacks coverage of security mechanisms and domain-specific needs [11]. Esser and Struss propose a template-based approach for functional testing but primarily focuses on test case generation from functional specs, with limited security criteria support [4]. Rupp *et al.* provide a requirements template emphasizing structure but may not suit all requirement types and lacks security and non-functional requirement details [18]. **Security requirements specification:** Several guides and templates aid in specifying security requirements. Kamalrudin *et al.* provide a comprehensive security requirements template covering authentication, integrity, confidentiality, availability, and non-repudiation [9]. However, it

may not encompass all system security requirements and lacks domain-specific considerations. Firesmith promotes reusable templates for specifying security requirements at the asset level [6]. However, finding detailed information about these templates in various databases can be challenging, limiting their usability [1,2,5]. Souag *et al.* introduce AMAN-DA, a method offering domain and application-level security requirements templates based on SIREN [21]. Pabuccu *et al.* present the Cube template for general software systems, adaptable for security and domain-specific requirements as needed [16]. **Self-adaptive systems and product lines requirements specification:** Mazo *et al.* [14] introduce a template for functional and non-functional requirements tailored to self-adaptive systems and product lines. It consists of nine sections covering conditions, system hierarchy, priority, activity characterization, objects, object details, conditionality, verification criteria, and RELAX statements. However, this template does not meet security requirements and lacks domain and application-level specifications. Proposed improvements include adding security criteria and mechanisms and improving the framework to simultaneously address domain and application requirements for better coverage, particularly for shared components.

3 Research Method

Action research, chosen for this study [15,23,24], involves intervening to improve a situation and learn from it. This approach aims to resolve issues, offer practical solutions, and investigate phenomena in their natural context [10]. It is cost-effective and relies primarily on researchers, reducing validity threats. Action research follows five phases: diagnosis (identifying problems), action planning (identifying solutions), taking action (implementing a solution), evaluating (examining consequences), and specifying learning (interpreting results and initiating new cycles) [22]. In this work, we conducted two action research cycles, each representing security requirements specification for a system.

In the **first cycle**, we analyzed the security requirements of two systems: the Remote Patient Monitoring System [8] and an Electric Vehicle (EV) Charging System proposed by the European Network for Cybersecurity[1]. The Remote Patient Monitoring System is an IoT device for health data transmission, while the EV Charging System powers electric vehicles. We introduced the first version of the new semi-structured Natural Language template for specifying security requirements, considering three solutions: adapting prose-style requirements from [8] using templates by Mazo *et al.*, ACE, and Kamalrudin *et al.* In the **second cycle**, we assessed the requirements specification for Medical Domain Systems or Devices proposed by the ANSM (Agence nationale de sécurité du médicament et des produits de santé)[2], which are employed for collecting patients' medical data. During this cycle, we considered three solutions: prose-style security requirements, initial SECRET template, and enhanced SECRET template (version 2) described in this paper.

[1] Electric Vehicles Charging System.
[2] ANSM'S GUIDELINE Cybersecurity of medical devices.

In each cycle, we followed these steps: ***(1) Diagnosing***: We encountered issues with security requirement specifications using prose style and Mazo *et al.*'s template initially. We conducted multiple mini-cycles to identify and resolve these problems, leading to the development of a new template. ***(2) Action Planning***: The Mazo *et al.* template could not adequately handle security aspects, such as criteria and mechanisms. We experimented with Kamalrudin *et al.*'s template and ACE in the first cycle, creating the SECRET template. In the second cycle, we refined SECRET and introduced Version 2, integrating elements from existing templates to maintain consistency. ***(3) Taking Action***: We identified security requirements gaps in each cycle and used the identified templates to establish a consistent pattern for requirement specification. ***(4) Evaluating***: We assessed if the templates covered 100% of security requirements, aiming for accurate representation while avoiding issues like ambiguity, complexity, or omission. ***(5) Specifying Learning***: After each cycle, we interpreted results to evaluate the strengths and limitations of the enhanced template. Collaboratively, we chose action research to assess the SECRET template's industrial effectiveness, conducting two cycles with different cases. However, we acknowledge that three cases may not fully validate the template. We used insights from the third case to improve it. Plans involve further refinement through multiple cycles with diverse industrial cases for real-world applicability.

4 Problems Identified in the Baseline Templates

In the first cycle of our study, we addressed security requirements for the Remote Patient Monitoring System, evaluating three templates: Mazo *et al.*'s, ACE, and Kamalrudin *et al.*'s. This led to the initial SECRET template. Identified template shortcomings and gaps, including missing security criteria and mechanisms, are documented in two online sources[3,4]. Notably, the security criteria within requirements, like Integrity or Confidentiality, were often embedded in identifiers rather than explicitly stated. For instance, requirements like "Identification Requirement" or "Physical Protection Requirement" implied specific security criteria but lacked explicit mention. Additionally, security mechanisms were often omitted from requirements, although they were essential for guaranteeing security. For instance, an "Immunity Requirement" failed to specify the corresponding security mechanism, "Antivirus: Immunity." These issues provided insights for refining and enhancing the SECRET template.

In the second action research cycle, using SECRET Version 1, refined from the first cycle, we specified ANSM's medical devices security requirements. This cycle addressed three key issues: the separation between domain and application security requirements, the distinction between problem and solution spaces, and the inclusion of security norms or standards. The identified shortcomings during this cycle are thoroughly documented in an online source[5], complete with

[3] Remote Patient Monitoring System Requirements.
[4] Electric Vehicles (EV) Charging System Requirements.
[5] Remote Medical Device Domain Requirements.

concise descriptions and examples for each issue. Firstly, there was no clear separation between domain-specific and application-specific security requirements. For instance, **R59** represented a domain-level requirement applicable to all connected medical devices, while **R40** pertained to specific devices within the same domain. Separating domain and application requirements would enhance clarity. Secondly, some security requirements, such as **R59** and **R40**, shared the same solution, applicable to various domain problems and potentially to application problems within the same domain. Separating the problem and solution spaces would facilitate reusing solutions for similar requirements. Lastly, the template lacked a dedicated section for specifying security standards or norms. For instance, **R25** mentioned complying with standard BS EN 50159. A standardized section for explicitly stating applicable norms or standards within the template would simplify its use for requirements engineers.

5 Proposed Template - SECRET

Through two action research cycles, we improved the Mazo *et al.*'s template [14], resulting in the first and second versions of the SECRET template. The first version, shown in Fig. 1[6] was divided into 11 parts. Parts 1–4 corresponded to sections 1-4 of Mazo *et al.*'s template, part 5 to the security criteria, part 6 to the object part, parts 7 and 8 are the conditionality in object and additional object details conforming to the Mazo *el al.* template, part 9 corresponds to the security mechanism, and parts 10 and 11 to parts 8 and 9 of Mazo *et al.*'s template, respectively. The second version of the SECRET template, presented in Fig. 2[7] was created to address three issues: (i) no separation of domain and application security requirements, (ii) no separation between problem and solution spaces, and (iii) missing capability to represent standards and norms in the template. This version was divided into three parts: domain specification in the problem space, application specification in the problem space, and domain and application specification in the solution space. Part 8 represents potential norms and standards associated with the requirements.

1-Conditions under which a behavior occurs. This component (1 - yellow) is identical in domain and application requirements. The options are: **(a) Requirements with logical conditions:** describe behaviors triggered only when a logical condition is achieved or when a sudden event happens ***IF*** *<condition or event>* ***THEN***. **(b) Requirements guided by the state:** describe behavior that must be completed while the system is in a specific state. ***WHILE*** | ***DURING*** *<activation state>*. **(c) Requirements with optional elements:** describe behavior that must be completed only if a specific feature is included. ***IN CASE*** *<included feature>* ***IS INCLUDED***. **(d) Requirements with temporary conditions:** describe a behavior that must happen after another behavior occurs.

[6] SECRET V1 : https://shorturl.at/bAVX5.
[7] SECRET V2 : https://shorturl.at/antSV.

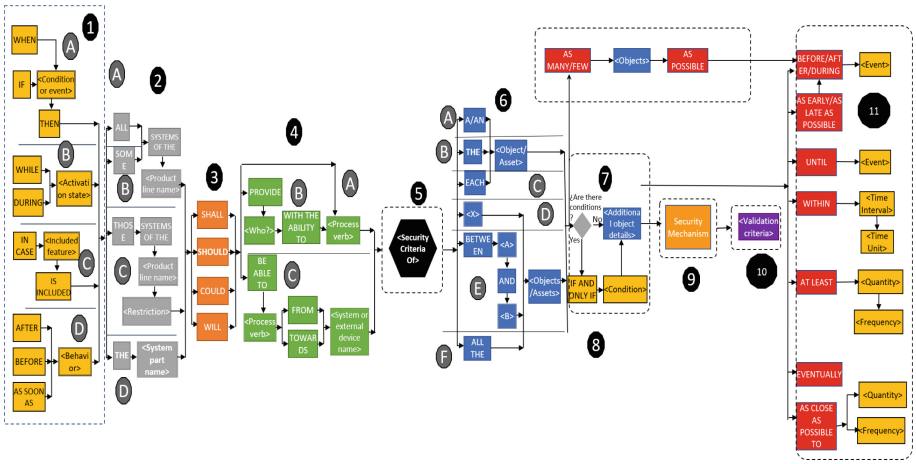

Fig. 1. SECRET Version 1

AFTER | ***BEFORE*** | ***AS SOON AS*** *<behavior>* . **(e) Requirements with complex conditions:** for complex conditional clauses, it is sometimes required to add keywords, such as When, While, or Where. It can help specify richer behaviors of the system.

2-Family of systems, systems or parts of a system. This component is different in domain and application requirements. **System or part of system:** It is illustrated by part (2 - gray) of the application problem space in Fig. 2. Since we are specifying a requirement for a specific known application, the following notation is used: Name of the system or a specific part of it. ***THE*** *<system or part name>* . **Family of systems:** It is illustrated by part (2 - gray) of the domain problem space in Fig. 2. In this case, we specify requirements for a domain. Thus, the following notations are used: (a) Name of all or some systems of a product line. ***ALL SYSTEMS OF THE*** | ***SOME SYSTEMS OF THE*** *<product line name>* . (b) Name of the product line and condition or restriction of some product line systems. ***THOSE SYSTEMS OF THE*** *<product line name> <restriction>* .

3-The degree of priority. It is the component (3 - orange) of Fig. 2. **(a) Essential requirements:** must be implemented to reach the success of the product or the product line. **SHALL** . **(b) Recommended requirements:** important but optional to reach the success of the product or the product line. **SHOULD** . **(c) Desirable requirements:** desirable, but not necessary, used to improve the user experience and customer satisfaction. **COULD** . We also added the fourth priority will. It indicates optional requirements where it is up to the technical team to implement them or not **WILL** .

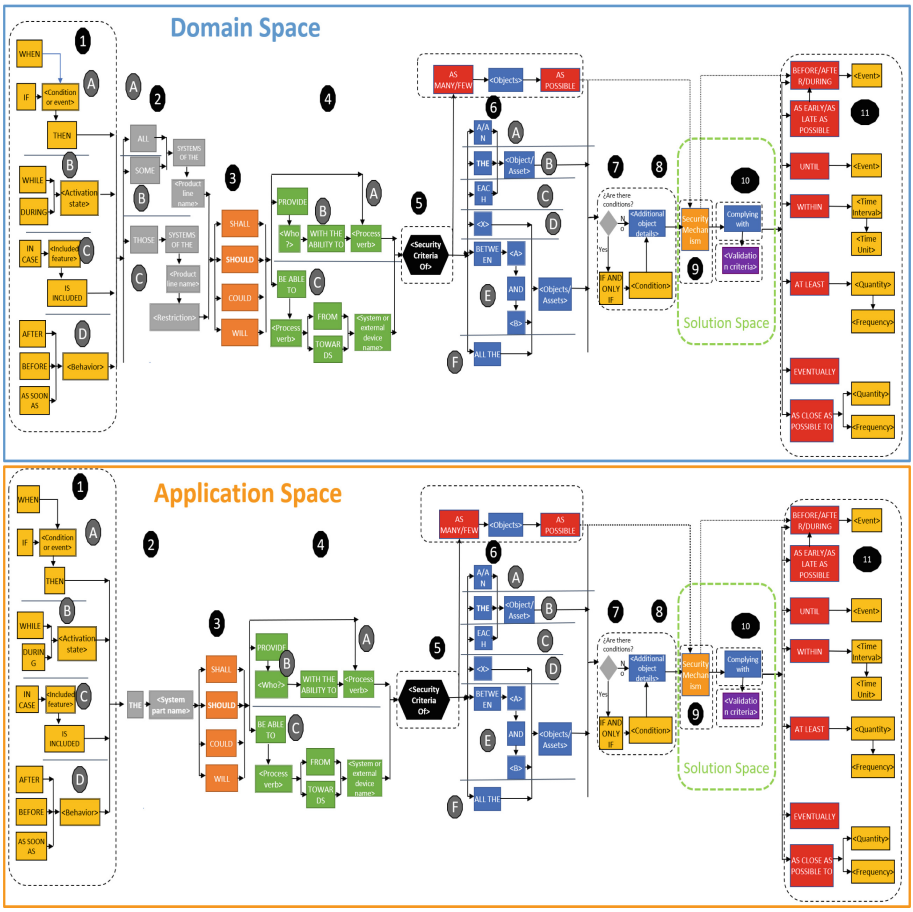

Fig. 2. SECRET Version 2

4-The activity It is the component (4 - green) of Fig. 2. There are three types of activities: **(a) Autonomous activity:** no user is involved, which indicates that the (sub) system or systems start and complete the behavior autonomously. *<process verb>* . **(b) User interaction:** the (sub) system or systems provide a user with the ability to employ a specific behavior started or completed by a user (actor) that interacts with the system(s). ***PROVIDE*** *<who?>* ***WITH THE ABILITY TO*** *<process verb>*. **(c) Interface requirement:** the system executes a behavior that relies on another entity. ***BE ABLE TO process verb>*** **(i) If the external system executes the behavior:** ***FROM*** *<system or external device name>* **(ii) If the behavior is executed by the system and interacts with another system or external device:** ***TOWARDS*** *<system or external device name>* .

5-Security Criteria This component (5 - black) of Fig. 2 represents the security goal or goals to be achieved by the requirement. It has the following notation: *<Security Criteria>* . An example of a security criterion is Authentication. <The Remote Monitoring System>$_{system}$<SHALL>$_{priority}$<guarantee >$_{processVerb}$< **the authentication** >$_{securityCriteria}$<of person or device>$_{object}$< with whom it is interacting>$_{additionalObjectDetails}$<by identity verification >$_{securityMechanism}$.

6-Object or Objects The object(s) or asset(s) are represented by the available ranges: **(a) Single object.** ***ONE*** *<object>* . **(b) A specific object.** ***THE*** *<object>* . **(c) Each object of a set.** ***EACH*** *<Object>* . **(d) Multiple objects.** *<X> <objects>* , where X is the number of objects. **(e) Range of objects.** ***BETWEEN*** *<A>* ***AND*** *<B> <objects>* . **(f) All objects in a set.** ***ALL THE*** *<objects>* An "of" is added before the object component as the requirement represents the need to guarantee the security criterion of an object, for example, the integrity of user data. <During transit>$_{Condition}$<The Remote Monitoring System>$_{system}$ <SHALL>$_{priority}$<guarantee>$_{processVerb}$<the integrity>$_{securityCriteria}$ <**of medical data**>$_{object}$<from an intruder>$_{additionalObjectDetails}$.

7-Conditionality in the object It is represented by part (9 - yellow) of Fig. 2. It has the following notation: ***IF AND ONLY IF*** *<condition>* .

8-The complementary details It is represented by component (10 - blue) of Fig. 2. It has the following notation: *<additional object details>* .

9-Security Mechanism The security mechanism of the requirement is considered a part of the solution since it indicates how and what mechanism to use to achieve the security criteria. It is represented by part (7 - orange) of Fig. 2. It has the following notation: *<Security Mechanism>* . An example of a security mechanism for authentication is identity verification. <The Remote Monitoring System>$_{system}$<SHALL>$_{priority}$< guarantee>$_{processVerb}$< *theauthentication* >$_{securityCriteria}$<of person or device>$_{object}$<with whom it is interacting>$_{additionalObjectDetails}$<**by identity verification**>$_{securityMechanism}$.

10-Validation Criterion or Standard The validation criteria of a security requirement can be a security norm or standard that it has to comply with. It is represented by part (8 - purple) in Fig. 2. It has the following notation: ***COMPLYING WITH*** *<Validation Criteria>* .

11-Relax requirements statements for self-adaptive systems It is represented by component (11 - red) of Fig. 2. The options are: (a) Should maximize or minimize the occurrence of a specific number of objects, as many or as few as possible. ***AS MANY*** | ***AS FEW*** *<object>* ***AS POSSIBLE*** . (b) Must be achieved before, during, or after a specific event. ***BEFORE*** | ***AFTER*** | ***DURING*** *<event>* . (c) Describes something that should be achieved as early

as possible or delayed as late as possible. ***AS EARLY AS POSSIBLE*** | ***AS LATE AS POSSIBLE***. (d) Must be sustained until an upcoming event. ***UNTIL*** *<event>*. (e) Must be sustained during a specific time interval. ***WITHIN*** *<time interval> <time unit>*. (f) Should reach a minimum frequency or time (until infinity). ***AT LEAST*** *<quantity> <frequency>*. (g) Behavior that should happen eventually. ***EVENTUALLY***. (h) Specifies something that happens repeatedly but has flexible frequency or quantity. ***AS CLOSE AS POSSIBLE TO*** *<quantity> <frequency>*.

6 Preliminary Evaluation

In evaluating the SECRET template, we organized two groups for each cycle: business analysts and technical reviewers. During the first cycle, one group used Mazo *et al.*'s template, while the other used SECRET - V1 to define security requirements for the Remote Patient Monitoring System and Electric Vehicles (EV) Charging System. Subsequently, technical reviewers assessed the resulting requirements. The Remote Patient Monitoring System had 15 prose-style requirements, while the EV Charging System comprised 101 requirements (excluding vendor-specific ones). When the first group's business analysts redefined the security requirements using Mazo *et al.*'s template, they encountered uncertainties. The technical reviewer identified issues in 17 Remote Patient Monitoring system requirements and all 101 requirements for the EV Charging System when using Mazo *et al.*'s template. These issues are categorized in Table 1. Conversely, in the other group, business analysts successfully re-specified the systems' requirements using the SECRET template, with all 17 and 96 security requirements receiving approval without any noted issues from the technical reviewer.

Table 1. Problems identified in the requirements in the first cycle

Problem identified	Nb. of requirements using the Mazo *et al.*'s template	Nb. of requirements using SECRET
Remote Patient Monitoring System		
Missing Security Criteria	17	0
Missing Security Mechanism	3	0
Electric Vehicles (EV) Charging System		
Missing Security Criteria	101	0
Missing Security Mechanism	101	5

In the second cycle, we identified security requirements for medical domain devices, resulting in 64 prose-style requirements. After excluding seven unrelated

requirements, the remaining 57 prose-style requirements were transformed into 61 security requirements using the SECRET template. However, compatibility issues arose with the first version of the SECRET template, which was extended in the second version. These issues are outlined in Table 2.

In evaluating security requirement templates, the first cycle revealed critical issues using Mazo et al.'s template, highlighting gaps in security coverage for complex systems. The second cycle demonstrated significant improvements in the SECRET template, attributing its success to iterative development, expert input, and meticulous alignment with prose-style requirements. Feedback from the initial cycle informed targeted refinements, ensuring enhanced clarity, comprehensive coverage, and seamless integration. Rigorous testing further solidified the second version's effectiveness, eliminating issues and showcasing the template's evolution toward robust and reliable security specifications.

The final SECRET template has been integrated into the VariaMos tool[8] for simplified domain and application security requirement specification. VariaMos offers two languages, "Application Requirements AC"[9] and "Domain Requirements AC"[10] implementing the template. These languages facilitate the execution, creation, editing, and deletion of security requirements and establish traceability relationships. This integration enhances the accessibility and usability of the SECRET template for security requirement specification.

Table 2. Problems identified in the requirements in the second cycle

Problem identified	Nb. of requirements using SECRET Version 1	Nb. of requirements using SECRET Version 2
No separation between domain and application security	61	0
No separation between problem and solution spaces	61	0
Missing standards or norms	4	0

7 Conclusions and Future Work

In this paper, we introduced the SECRET template for specifying security requirements. We built upon Mazo *et al.*'s template, aiming to address its limitations in capturing security requirements. Our research, conducted through action research, focused on enhancing the representation of security requirements. We identified that Mazo *et al.*'s template could be improved by incorporating structural and security components from the ACE and Kamalrudin *et al.* templates.

[8] http://www.variamos.com/.
[9] https://shorturl.at/cPSV1.
[10] https://shorturl.at/loqF1.

Our study included three industrial cases, revealing significant enhancements in security requirements concerning cost, time, and quality standards. To further strengthen our findings, future work involves experimenting with additional reference templates beyond Mazo *et al.*, ACE, and Kamalrudin *et al.* and comparing their outcomes with the SECRET template. Extending the evaluation to diverse industrial cases and domains will provide a broader perspective on the SECRET template's utility. Additionally, we plan to integrate a security ontology into the SECRET template to generate security requirements based on specific security criteria, enhancing security coverage. The SECRET template and its associated ontology form essential guides within a comprehensive framework for specifying, formalizing, and analyzing hardware and software system security.

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Towards Automated Classification of Repetitive Themes in Brazilian Courts with *LegalClass*

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Abstract. The growing influx of lawsuits in judicial systems presents a pressing challenge for timely case resolution. The Sao Paulo Justice Court is particularly noteworthy, boasting the world's largest caseload with an 84% congestion rate and an average processing time of over seven years. To address this issue, this article introduces *LegalClass*, a computational tool designed to expedite case processing. *LegalClass* employs natural language processing and an array of machine learning algorithms-such as Support Vector Machines, Logistic Regression, Naive Bayes, K-Nearest Neighbors, and Convolutional Neural Networks-for the automated classification of lawsuits, with a focus on repetitive legal themes. Developed in collaboration with the University of São Paulo, this tool aims to significantly enhance the efficiency of the judicial system by harnessing the capabilities of artificial intelligence and data science. This study uses *LegalClass* to assess the performance of machine learning algorithms in categorizing lawsuits according to predefined themes set by the Superior Court of Justice. While automation through text classification has shown promise in handling vast volumes of legal texts, ongoing improvements in methods and techniques are essential for increasing both efficiency and accuracy. Continued research in this rapidly evolving field is crucial for meeting the changing needs of legal information processing.

Keywords: Lawsuit classification · Repetitive themes · Natural language processing · Machine learning · Artificial intelligence · Jurisdictional provision

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1 Introduction

The global litigation landscape is witnessing an unprecedented surge, with the Sao Paulo Justice Court (Tribunal de Justiça de São Paulo - TJSP) leading in case volume. This court not only has the highest number of lawsuits worldwide but also has an alarming congestion rate of 84% [9]. Moreover, it has the longest average case processing time among state-level courts in Brazil, stretching to seven years and five months. The sheer volume of paperwork burdens court staff considerably, making it imperative to seek automated solutions to accelerate case resolutions.

In the Brazilian legal system, the concept of Repetitive Appeal offers a streamlined approach to handling multiple special appeals involving identical legal disputes. Selected cases are escalated to the Superior Court of Justice (Superior Tribunal de Justiça - STJ) for adjudication, with related issues in abeyance. Once the court resolves the repetitive appeal, its ruling becomes a canonical "Repetitive Theme", applicable to all suspended cases.

Recognizing the need for technological interventions, the University of São Paulo (USP) has collaborated with TJSP to foster research and development in artificial intelligence, specifically in data science for legal applications. This paper introduces *LegalClass*, a computational tool leveraging natural language processing and machine learning algorithms to analyze and categorize court decisions. The algorithms include Support Vector Machines [4], Logistic Regression [6], Naive Bayes [8], K-Nearest Neighbors [2], and Convolutional Neural Networks. *LegalClass* aims to classify lawsuits into STJ's Repetitive Themes, providing individual and batch processing options and statistics for previously classified cases.

Although various tools employing machine learning for classification tasks exist in the literature [3,5,11], there is a conspicuous absence of text classification solutions explicitly designed for the legal domain in the Portuguese language. This gap in research accentuates the novelty and necessity of *LegalClass*.

Despite the promise of automated text classification, the field is still in its infancy and requires more robust, accurate methodologies to help practitioners rapidly sift through critical information. As such, this paper contributes to ongoing research to refine text classification techniques for enhanced decision-making and productivity.

The remainder of this paper is organized as follows: Sect. 2 details the proposed tool, Sect. 3 recounts its application to a real-world case study, and Sect. 4 concludes with a summary and directions for future research.

2 Proposed Tool

This section outlines the functionality of our web-based tool, *LegalClass*, designed to evaluate machine learning algorithms for classifying Portuguese legal cases into STJ repetitive themes.

2.1 Training

The initial version of *LegalClass* can classify legal cases into five predefined repetitive themes: 0929, 1015, 1033, 1039, and 1101. Table 1 summarizes each theme's focus. Our dataset consists of 10,684 legal decision texts distributed across these themes as follows: theme 0929 has 2,065 samples, theme 1015 comprises 1,237 samples, theme 1033 contains 5,356 samples, theme 1039 includes 526 samples, and theme 1101 has 1,500 samples. The data were partitioned into an 85% training set and a 15% validation set.

Table 1. Summarized Repetitive Theme Descriptions

Theme	Concise Descriptions
0929	Pertains to double repetition rules under Consumer Protection Code Article 42
1015	Involves the financial responsibility of HSBC Bank Brasil S/A due to its business succession with Banco Bamerindus S/A, particularly concerning inflationary adjustments to savings accounts
1033	Addresses the reset of the statute of limitations for compliance claims related to collective rulings due to the filing of protest actions
1039	Focuses on the determination of the initial term for indemnity claims against insurers in active or expired Housing Financial System contracts
1101	Examines the final term for the applicability of interest rates in actions related to inflationary adjustments in savings accounts

We removed stop words and punctuation marks for text preprocessing and performed specific term transformations relevant to the Brazilian legal context. The Natural Language Toolkit (`nltk`) and `string` libraries facilitated this preprocessing step. The texts were then vectorized using the TF-IDF technique, generating a feature set of 64,687 bi-grams and tri-grams. We employed several machine learning algorithms for multi-class classification, including a Calibrated Classifier with Support Vector Machines (SVM), Logistic Regression (LR), Multinomial Naive Bayes (NB), and K-Nearest Neighbors (KNN).

2.2 User Interface

The *LegalClass* tool offers a user-friendly web interface with three primary functions: online classification, batch classification, and query of past classifications. Built using the open-source *Streamlit* library (version 1.10.0), the tool provides real-time, scalable solutions for classifying legal texts.

According to Fig. 1, in the online option, it is possible to select one or more classifiers in (1) and select the document text to be classified in (2). The document text chosen is shown in (3). By the "Process" button in (4), it is possible to execute the classification model code. As a result, two tables are displayed. The former (5) shows the probabilities of each theme of each classifier. The latter (6) shows the average of the probabilities of each theme. The theme is suggested, and its description is displayed in (7).

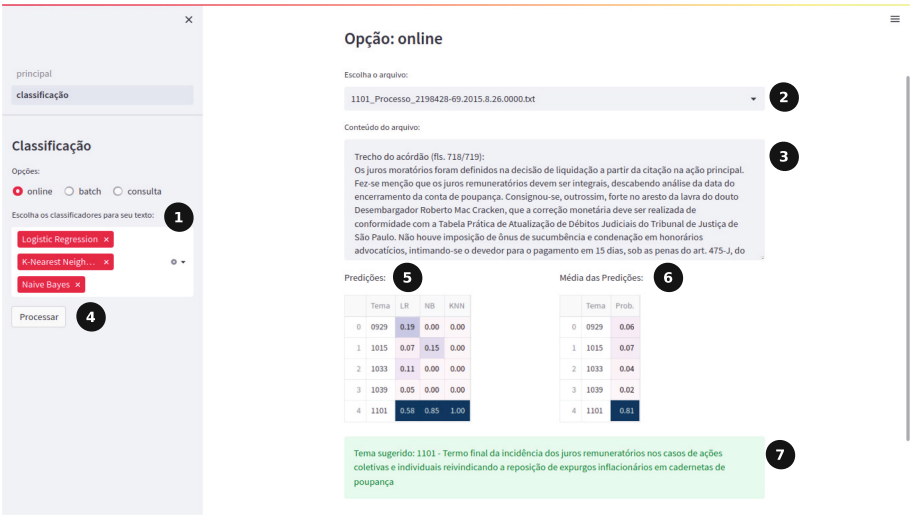

Fig. 1. Online Classification Interface.

According to Fig. 2, in the batch option, it is possible to select one single classifier in (8) and download the file in ".csv" format with the document text list to be classified in (9). The result of classification is another list with document text identifier and their respective probabilities of bellowing to each repetitive theme. This result is shown in (10), where the probabilities are displayed in a heatmap, where the highest probabilities are the darkest. This result is also saved in a folder, and this information is presented in (11). According to Fig. 3, in the query option, it is possible to select a list of previously classified document texts in (12). This list, shown in (13), is a heatmap with document text identifier and their respective probabilities. By the "See statistics" button in (14), it is possible to obtain some information about the document text set and their probabilities, such as count, mean, standard deviation (std), minimal, statistical quartiles(25%, 50%, 75%), and maximal, shown in (15). In (16), it is shown the amount (we used the symbol "#") and the percentage (we used the symbol "%") of samples with probabilities greater than or equal to 50%, %, 70%, 80%, and 90%. The latter (6) shows the average of the probabilities of each theme. The theme is suggested, and its description is displayed in (7).

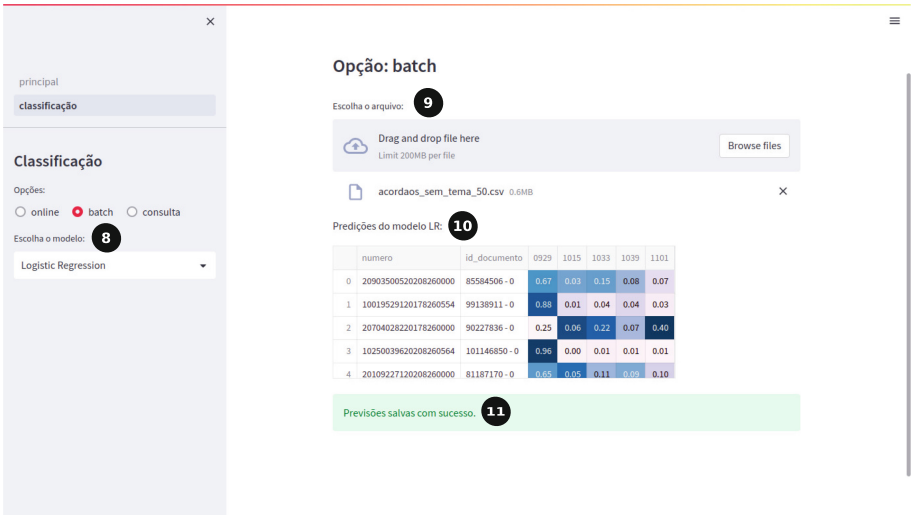

Fig. 2. Batch Classification Interface.

3 Case Study

This section outlines an experiment using *LegalClass* to categorize lawsuit decisions. We employ four machine learning classifiers and follow the protocols established in previous software engineering literature [1,7,10].

3.1 Data Description and Preparation

TJSP civil servers selected twelve lawsuit decisions comprising four themes-0929, 1015, 1033, and 1101-each with a designated difficulty level for classification. The difficulty levels are categorized as follows:

- **Easy (E)**: The lawsuit text explicitly mentions the repetitive theme, e.g., "Theme 1033".
- **Medium (M)**: The text contains easily identifiable keywords, though it lacks an explicit mention of the repetitive theme.
- **Hard (H)**: The text neither mentions the repetitive theme explicitly nor contains easily identifiable keywords.

We employed *LegalClass*'s online platform to test each of the four machine learning classifiers-SVM, RL, NB, KNN-individually and in various combinations, resulting in fifteen distinct approaches. Subsequently, we evaluated the probabilities associated with each classification to gauge the confidence level of predictions. Each lawsuit text was tested under 180 scenarios comprising individual classifiers and their committees.

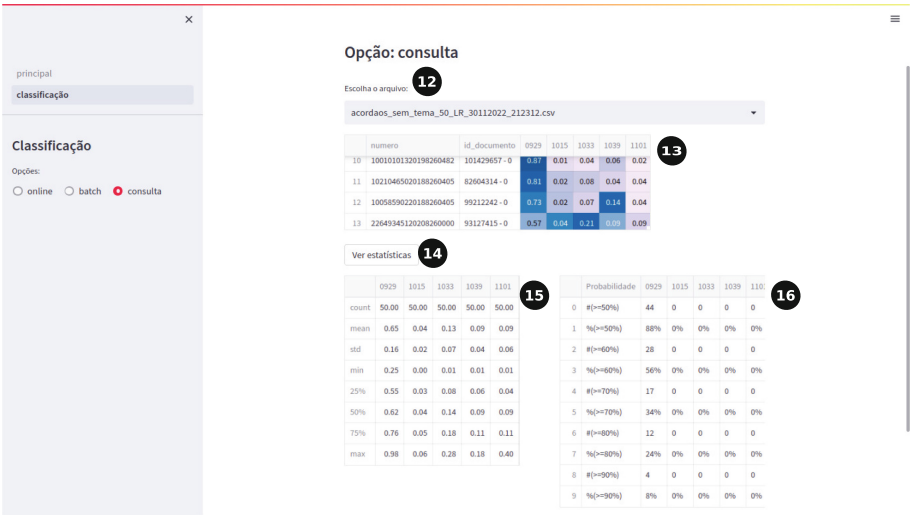

Fig. 3. Query Classification Interface.

3.2 Objective

The experiment aims to answer the research question (RQ): Can *LegalClass* efficiently identify the most effective classification approach for repetitive lawsuit themes?

Our hypothesis (H) posits that *LegalClass*'s probability outputs aid in selecting the best classification approach.

3.3 Variables

Independent Variables:

- Classifiers: Four ML classifiers and their combinations.
- Texts: Twelve lawsuit decisions.

Dependent Variables:

- Response: Classified as right or wrong.

3.4 Results

We present the experimental results obtained through machine learning classifiers on the *LegalClass* platform. As an illustrative example, Fig. 4 showcases the output generated using the "A15" approach, which employs a committee comprising the classifiers SVM, RL, NB, and KNN. The document under consideration is denoted as "T4", a text from theme 1015 that is categorized as 'easy' to classify and carries the process number 2112337-73.2015.8.26.0000.

In this particular instance, all classifiers successfully identified the correct theme. The confidence level in identifying theme 1015 was as follows: 92% for SVM, 73% for LR, for both NB and KNN. When combining the results from all four classifiers into the committee, the overall probability of correctly identifying theme 1015 was 91%.

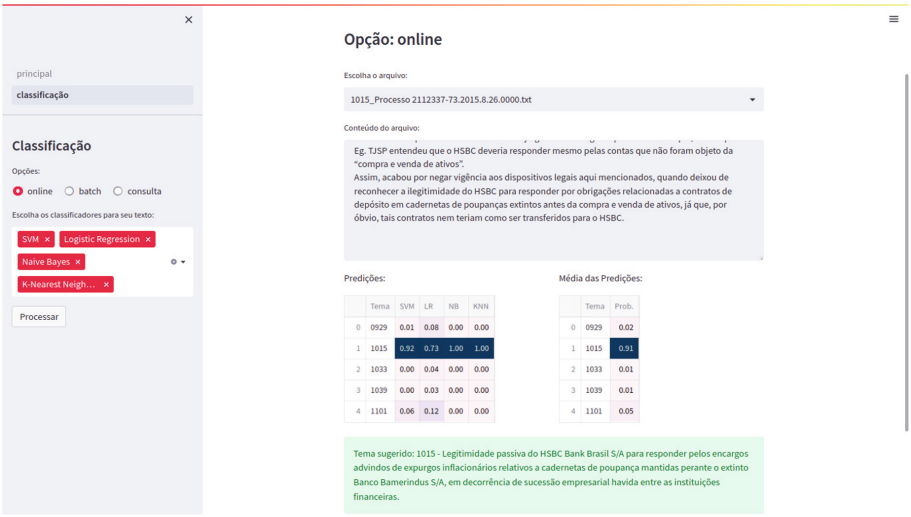

Fig. 4. Example of Classification Output.

Table 2 shows the responses (right (✓) or wrong(✗)) to output the question approach righted or not the theme of the lawsuit decision.

According to Tables 2, incorrect predictions were made only for the texts "T8" and "T12". Text "T8" is of medium difficulty and is associated with theme 1033, carrying the process number 2080844-73.2018.8.26.0000.

For "T8", inaccurate predictions occurred when using the "A3" and "A8" approaches. Specifically, the "A3" approach uses the NB classifier, while "A8" employs a committee comprising the RL and NB classifiers. The confidence level for the text correctly belonging to theme 1033 was low: 22% for "A3" and 39% for "A8".

Figure 5 presents a snippet of the *LegalClass* output when the "A15" approach was employed, which involves a committee of all four classifiers (SVM, RL, NB, KNN). The first frame of the figure indicates the individual probabilities from each classifier for the text belonging to theme 1033: 79% for SVM, 56% for LR, 22% for NB, and 100% for KNN.

Table 2. Response of Classifiers or Committees

Appr.		Texts											
		T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
A1	SVM	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
A2	LR	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✗
A3	NB	✓	✓	✓	✓	✓	✓	✓	✗	✓	✓	✓	✗
A4	KNN	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✗
A5	SVM, LR	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✗
A6	SVM, NB	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✗
A7	SVM, KNN	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✗
A8	LR, NB	✓	✓	✓	✓	✓	✓	✓	✗	✓	✓	✓	✗
A9	LR, KNN	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✗
A10	NB, KNN	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✗
A11	SVM, LR, NB	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✗
A12	SVM, LR, KNN	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✗
A13	SVM, NB, KNN	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✗
A14	LR, NB, KNN	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✗
A15	SVM, LR, NB, KNN	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✗

The second frame displays the average probability, considering all four classifiers. In this case, the overall probability of correctly identifying theme 1033 was 64%, as determined by the committee of four classifiers.

Predições:

	Tema	SVM	LR	NB	KNN
0	0929	0.04	0.21	0.52	0.00
1	1015	0.02	0.04	0.00	0.00
2	1033	0.79	0.56	0.22	1.00
3	1039	0.01	0.07	0.15	0.00
4	1101	0.15	0.11	0.12	0.00

Média das Predições:

	Tema	Prob.
0	0929	0.19
1	1015	0.01
2	1033	0.64
3	1039	0.06
4	1101	0.10

Fig. 5. Probabilities of Text "T8" by *LegalClass*.

Text "T12" is categorized as having a high difficulty level for classification and is associated with theme 1011. It carries the process number 2060043-78.2014.8.26.0000. Interestingly, only the "A1" approach, which utilizes the SVM

Predições:

	Tema	SVM	LR	NB	KNN
0	0929	0.23	0.32	0.00	0.00
1	1015	0.13	0.15	1.00	1.00
2	1033	0.02	0.13	0.00	0.00
3	1039	0.01	0.08	0.00	0.00
4	1101	0.62	0.32	0.00	0.00

Média das Predições:

	Tema	Prob.
0	0929	0.14
1	1015	0.57
2	1033	0.04
3	1039	0.02
4	1101	0.23

Fig. 6. Probabilities of Text "T12" by *LegalClass*.

classifier, correctly identified the text's theme with a confidence level of 62%. All other approaches led to incorrect predictions.

Figure 6 illustrates a segment of the output generated by *LegalClass* when employing the "A15" approach, a committee of all four classifiers (SVM, RL, NB, KNN), to categorize "T12". The first frame of the figure details the individual probabilities assigned by each classifier for the text being part of theme 1101: 62% by SVM, 32% by LR, 0% by NB, and m 0% by KNN. The second frame displays the average probability, aggregating results from all four classifiers. According to this committee-based approach, the overall likelihood of "T12" belonging to theme 1101 was a mere 23%.

The tool *LegalClass* facilitated the evaluation of the prediction accuracy and confidence levels for SVM, LR, NB, and KNN classifiers across various text difficulty levels as classified by TJSP civil servers.

Easy Texts: All approaches accurately predicted the themes for texts considered 'easy' (T1, T4, T7, T10). For instance, the likelihood of text T1 belonging to theme 929 exceeded 97% across all approaches, while for text T4 and theme 1015, the probability was above 73.

Medium Texts: For 'medium' difficulty texts (T2, T5, T8, T11), all methods were accurate except for text T8. This text yielded incorrect predictions when evaluated using approaches A3 and A8.

Hard Texts: Among the texts classified as 'hard' (T3, T6, T9, T12), only text T12 posed a challenge; accurate prediction was achieved solely through the A1 approach using the SVM classifier.

Theme-specific Insights:

– Texts under theme 929 consistently exhibited the highest probabilities of accurate classification, surpassing 94

– For theme 1015, probabilities remained above 67
– Themes 1033 and 1101 revealed the most variability in prediction confidence, ranging from 22

Research Conclusion: Based on the response and probability data gathered through the *LegalClass* interface, we recommend the Support Vector Machine (SVM) as the most reliable classifier for predicting whether a text belongs to one of the five repetitive themes under study.

4 Conclusion

As judicial workloads grow, automation and modern techniques are increasingly essential. One challenge in Brazil's judicial system is efficiently classifying lawsuits into predefined repetitive themes. This paper presented *LegalClass*, a web-based tool designed to tackle this issue by employing machine learning algorithms for text classification.

Our tool allows for categorising individual or multiple legal texts and provides theme suggestions and associated probabilities. Though initially equipped with four traditional machine learning algorithms, the tool's architecture permits the straightforward inclusion of additional algorithms and themes.

Using a case study, we demonstrated the tool's efficacy by employing it on real-world data categorized by civil servers at TJSP. The SVM algorithm emerged as the most effective classifier, correctly categorizing all provided texts and offering an intuitive, user-friendly interface.

Automated text classification holds significant promise for enhancing judicial efficiency, but further research and development are required to refine this technology. Future advancements in this domain can yield more precise and efficient systems, aiding decision-makers in navigating extensive data sets more effectively.

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LegalSum: Towards Tool for Evaluation for Extractive Summarization of Brazilian Lawsuits*

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Abstract. The increasing volume and complexity of legal documents have led to a growing interest in text summarizing for legal texts. In this context, this paper presents *LegalSum*, a tool for automatically summarizing lawsuits in Portuguese, aiming to improve the efficiency of legal professionals and researchers. The tool is equipped with a legal-domain expression dictionary, which enhances the accuracy of summarization. It provides various algorithms such as Word Frequency, KL-Sum, Reduction, Edmunson, LSA, LexRank, TextRank, and Pagerank, as well as a committee approach that combines multiple algorithms. The architecture of *LegalSum* is modular and flexible, allowing new algorithms to be easily integrated. The tool was evaluated using the metrics Rouge (Rouge-1, Rouge-2 and Rouge-L) obtaining promising results. This paper contributes to the development of summarization tools for the legal domain, offering a valuable resource for legal professionals and researchers in the field.

Keywords: Legal text summarization · Natural Processing Language · Extractive Summarizing · Rouge Metric · Real-world Application · Intelligent Technique

1 Introduction

Text summarization techniques for legal documents have been on the rise in recent years, as highlighted by mainstream news outlets like Forbes [10].

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AI-driven applications such as document review, legal research, due diligence, contract analysis, and legal outcome prediction all rely on text summarization, which offers potential benefits to law firms in terms of time savings and enhanced efficiency.

As legal documents become increasingly voluminous and complex, the demand for efficient and effective summarization tools is expected to grow. Legal professionals and researchers rely on text summarization to quickly identify and comprehend crucial information within intricate legal documents, ultimately saving substantial time compared to manual reading. Additionally, it helps mitigate the risk of overlooking critical details or misinterpreting the content [13]. The need for automated reading processes is particularly evident in the Sao Paulo Justice Court (Tribunal de Justiça de São Paulo - TJSP), which holds the highest number of lawsuits globally and has an 84% congestion rate with an average processing duration of seven years and five months. Automating this reading process not only saves time but also expedites lawsuit resolutions.

However, evaluating the quality of a summary presents challenges, as there is no universally accepted standard for summarization single documents or sets of documents [21]. Additionally, defining what constitutes a practical summary remains open-ended. Research indicates a need for more consensus among individuals when assessing and generating summaries. The absence of standardized assessment metrics and diverse evaluation criteria complicates summary evaluation.

This paper introduces *LegalSum*, a tool designed for automatically summarization Portuguese-language lawsuits. *LegalSum* incorporates a legal-domain expression dictionary for more precise summarization and offers various algorithms such as Word Frequency, KL-Sum, Luhn, Reduction, Edmunson, LSA, PageRank, TextRank, and LexRank. It also employs a committee of algorithms and features a modular and flexible architecture, allowing for integrating new algorithms. To assess its performance, we applied *LegalSum* to summarize lawsuit decisions in a real TJSP case, employing human evaluators and the Rouge performance metric.

The remainder of this paper is organized as follows: Sect. 2 reviews related works, while Sect. 3 provides background information and a brief overview of the techniques employed. Section 4 discusses the tool and presents a case study. Finally, Sect. 5 summarizes the main conclusions and outlines future research directions.

2 Related Work

Legal text summarization is a burgeoning field with the potential to transform legal document handling. Recent research explores various aspects of legal text summarization, including natural language processing techniques and specialized algorithms. Nunez-Robinson et al. [19] compared transformer-based models for legal text summarization, highlighting BART and T5 as top performers. The study emphasized the impact of training data size and fine-tuning. Bhattacharya

et al. [4] evaluated summarization algorithms (LexRank, TextRank, LSA) on Brazilian legal cases. TextRank and LSA outperformed LexRank, demonstrating potential for combining NLP and ML. Huang et al. [12] introduced a two-stage approach using named entity recognition and supervised ML to summarize Chinese civil cases with high precision and recall. Jain et al. [14] proposed a deep clustering approach for legal document summarization, outperforming TextRank and LSA on Canadian legal cases. Begum et al. [3] assessed an automated summarization tool for Brazilian legal cases, noting its high recall but low precision when compared to human-generated summaries. Zhong et al. [27] used iterative masking of predictive sentences, outperforming traditional summarization techniques in summarization U.S. Supreme Court decisions. Sheik et al. [23] employed deep learning with masking to enhance summarization quality, showing promise in handling complex legal language and jargon in Canadian legal cases. Anand et al. [1] proposed a mask-based approach to focus on relevant sentences, improving accuracy and relevance in summarization legal texts. Deroy et al. [7] used ensemble methods and masking to improve extractive summarization for Indian legal case judgments, outperforming other techniques.

These studies collectively contribute to the advancement of legal text summarization, exploring various approaches and their potential impact on the field.

3 Background

Text summarization is a procedure that condenses a lengthy text document into a shorter and more comprehensible summary to highlight the essential points of the document. This task involves identifying and extracting the document's crucial information, which is then used to generate a brief and well-structured summary. The resulting summary must be coherent and fluent to convey the intended audience's key points effectively. Text summarization can be broadly categorized into two main approaches: extractive summarization and abstractive summarization. Extractive summarization involves selecting and condensing the most important sentences or phrases from a given document to create a summary. This approach typically involves ranking sentences based on relevance and importance and selecting the top-ranked sentences for inclusion in the summary. Extractive summarization is commonly used in news articles and a scientific papers summarization [22]. Abstractive summarization involves generating a summary that is not simply a subset of the original text but rather a new and original text that conveys the essential meaning of the original document. Abstractive summarization often involves using natural language processing (NLP) techniques to generate a fluent and coherent summary [2]. This study uses extractive summarization to reduce the analysis time of the lawsuit documents performed for TJSP force work.

3.1 Algorithms

Considering that *LegalSum* is a tool dedicated only to extractive techniques, we describe the techniques employed in this work next.

- **Word Frequency:** In this method, the frequency of all words in the text corpus is computed and recorded in a dictionary. Subsequently, the text corpus is tokenized, and the sentences that contain more frequently occurring words are retained for inclusion in the final summary data [11].
- **PageRank:** This is a well-known algorithm used to evaluate the significance of web pages by computing a ranking for each page. PageRank has been adapted for text summarization by treating sentences as nodes in a network and using the algorithm to identify the most important sentences in a document [5].
- **TextRank:** It is a graph-based ranking model for text processing, which leverages Google's PageRank algorithm to identify the most important sentences in a given text. The TextRank algorithm begins by segmenting the input text into individual sentences. Next, it constructs a graph where the nodes represent the sentences, and the edges between them indicate any overlapping words. Finally, by applying PageRank to this graph, TextRank identifies the most significant nodes, which correspond to the most important sentences in the text, forming the basis of the summary [18].
- **LexRank:** This algorithm is an unsupervised machine learning technique that leverages the TextRank method to summarise the input sentences. Specifically, the algorithm employs vector-based algorithms and cosine similarity measures to determine the minimum cosine distance among various words in the text corpus. The more similar words are grouped, forming the basis for generating the summary [9].
- **LSA (Latent Semantic Analyzer):** The Latent Semantic Analyzer algorithm utilizes a technique known as data decomposition to transform the text data into a lower-dimensional space. This technique allows LSA to capture the semantic structure of the input text while generating a summary. By representing the text in a reduced dimensional space, LSA can identify and extract essential information while preserving the text's overall meaning [6].
- **Luhn:** This approach for text summarization relies on a frequency-based method that involves computing the term frequency-inverse document frequency (TF-IDF) of the words in the input text. This approach assigns weights to the words based on their frequency in the text and relevance to the entire corpus of documents [17].
- **KL-Sum:** This algorithm selects sentences with a similar word distribution to the original text. It aims to minimize the Kullback-Leibler divergence (KL-divergence), which measures the difference between two probability distributions. The algorithm employs a greedy optimization approach and iteratively adds sentences until the KL-divergence criterion decreases. By doing so, KL-Sum can produce a summary that preserves the original text's main ideas and fundamental concepts [15].

- **Edmunson:** This algorithm suggests a subjectively weighted combination of features instead of using feature weights derived from a corpus. In addition to the features commonly used in Luhn's method, Edmundson's algorithm also proposes the inclusion of several other features, such as position, word frequency, cue words, and document structure (such as headlines, titles, subtitles) [8].
- **Graph Reduction:** This approach identifies the most important sentences from a single document by assigning importance to the vertices within a graph. The technique employs undirected and weighted graphs to implement text-based ranking, with documents or sentences represented as nodes and edges connecting nodes that share standard information. Sentence scoring is achieved by initializing weights to the nodes of the graph. The graph-based approach to text summarization is a powerful method that utilizes graph theory to extract essential information from a document or text [26].

3.2 Evaluation Metrics

When assessing the quality of a summary, various evaluation metrics come into play, involving both human evaluators and automated methods. These metrics consider coverage, grammatically, redundancy avoidance, essential content inclusion, structure, and coherence. One widely used automated evaluation metric is **ROUGE** [16]. ROUGE employs recall-oriented understudy methods to measure a summary's quality by comparing it to human reference summaries. Several variations of ROUGE exist, with the most common ones highlighted below:

- **ROUGE-n:** This metric evaluates the overlap of n-grams (typically two or three) between the reference and candidate summaries. The ROUGE-n score is calculated based on the number of common n-grams (p) and n-grams found only in the reference summary (q) using the formula $ROUGE - n = p/q$.
- **ROUGE-L:** ROUGE-L employs the longest common sub-sequence (LCS) to assess the similarity between the two text sequences. A higher LCS score indicates greater similarity between texts. It is important to note that this metric requires all n-grams to be consecutive sequences of words.
- **ROUGE-SU:** ROUGE-SU, or skip bi-gram and uni-gram ROUGE, evaluates both bi-grams and uni-grams. It allows for the insertion of words between the first and last words of bi-grams, accommodating non-consecutive word sequences.

4 Proposed Tool

This section describes our web tool *LegalSum*, which supports evaluating different algorithms in automatically summarising Portuguese lawsuit tasks.

4.1 Description

LegalSum has an easy-to-use graphical interface in Portuguese, c.f. shown in Fig. 1. First, we describe every feature of the tool after we report detail regarding

Fig. 1. *LegalSum* graphical interface.

materials and methods used in tool development. We enumerate every feature in Fig. 1, from 1 to 6, so explain next.

1. File choice. The files to be summarised get in a specific folder. In this pop-up component, it is possible to choose which one.
2. Approach choice. There are two approaches to summarization. The former finds the keywords in the text, and the latter is by algorithms. It is possible to choose one of them or both. When the first checkbox is selected, the summarization takes into account keywords. Such keywords are saved in a specific folder file, where the users can update them whenever they deem it necessary. When the second checkbox is selected, the summarization is performed by a algorithm.
3. Number of sentences. This slider is a component that allows choosing the number of sentences the users want in their summary. The minimal number is one, and the maximal number is the number of sentences of text chosen.
4. Algorithm choice. There are nine options: Word Frequency, KL-Sum, Reduction, Edmunson, LSA, LexRank, TextRank, and Pagerank, more one that is a committee. The committee corresponds to execution of all algorithms, where they are choose, the sentences more frequent in summarization done by algorithms. New algorithms can be easily incorporated into the tool.
5. Saving. In this button, the user can download their summarize so with visualizing the document in format `.pdf`, with sentences selected highlighted.
6. Feedback. In this option, the user can test the summary produced by one of the algorithms or committees. The goal is improve the tuning of algorithms that do not satisfied to users, or even delete them of tool. There are three radio buttons with the option: “Bad”, “Regular”, and “Good”.

To build our tool, we used the open-source library *Streamlit*[1] (version 1.10.0) with Python (version 3.8.9) programming language. NLTK (Natural Language Toolkit) Python libraries (version 3.7) were used for classification, tokenization, stemming, tagging, parsing, and semantic reasoning tasks. Sumy Python library (version 0.11.0) was used to implement the summarization algorithms.

4.2 Case Study

One of the challenges encountered by the São Paulo Court of Justice is determining whether a lawsuit can be classified as repetitive. A repetitive theme refers to a legal concept denoting a category of legal cases under appeal characterized by identical theses founded on uniform questions of law. In such cases, multiple legal actions exhibit remarkable similarities in the core legal arguments and the legal issues at hand, indicating a recurring pattern or theme in the litigation process. These cases are typically grouped due to their common legal grounds, facilitating streamlined legal analysis and decision-making processes [25]. Each day, civil servants at TJSP must read dozens of lengthy lawsuit decisions to determine which ones can be classified as repetitive.

Experimentation Setup. TJSP civil servers selected five repetitive themes, and for every one of these themes, they selected three lawsuit decisions, totalizing fifteen documents to be summarized by *LegalSum*. Then, the structure of handled corpus is formatted by linear text from lawsuit decisions. TJSP civil servers highlighted essential parts of these documents and assigned a difficulty score. According to this score, a lawsuits decisions is considered "Easy", when it explicitly indicates the repeating theme number; "Medium", when it has a broad foundation, with keywords that are easier to find, although the text does not explicitly indicate the repetitive theme; "Hard" when it does not indicate the repetitive theme, presents few keywords.

The goal is to measure how much the summarization produced by *LegalSum* are similar to highlighted parts by TJSP civil servers. Then, we use ROUGE to check the tool's performance.

Experimentation Results. The Rouge metrics (1,2, L and S) [16] were calculated for all summarization algorithms of the proposed tool together with the three lawsuits decisions, of difficulty "Easy", "Medium" and "Hard", of one of repetitive themes, being these considered summaries of references for the evaluation experiment. In Table 1, the *F-score* value for Rouge-1, Rouge-2, Rouge-L and Rouge-S is listed for all summarizers of the tool.

According to Table 1, the LSA, Word Frequency and Edmundson algorithms have the best F-score value for the Lawsuit Decision - Easy in all Rouge metrics considered in comparison to the values of the other summarization algorithms. This result can be explained by the nature of the algorithms that is related to

[1] https://streamlit.io/.

Table 1. F-score values for Rouge (1,2, L and S) for the repetitive theme.

Summarizers	Lawsuit Decision - Easy				Lawsuit Decision - Medium				Lawsuit Decision - Hard			
	Rouge-1	Rouge-2	Rouge-L	Rouge-S	Rouge-1	Rouge-2	Rouge-L	Rouge-S	Rouge-1	Rouge-2	Rouge-L	Rouge-S
Word Frequency	**0.6593**	**0.6312**	**0.6535**	**0.6564**	0.1453	0.0337	0.1038	0.1224	**0.2613**	**0.1538**	**0.1956**	**0.2124**
PageRank	0.1518	0.0462	0.1032	0.1138	0.1362	0.0296	0.0947	0.1173	0.1179	0.0125	0.0970	0.1031
TextRank	0.2804	0.2313	0.2653	0.2653	**0.1553**	0.0212	**0.1221**	**0.1286**	0.1131	0.0119	0.0828	0.0828
LexRank	0.1223	0.0502	0.1072	0.1175	0.0966	0.0115	0.0837	0.0837	0.0991	0.0097	0.0709	0.0709
LSA	**0.6593**	**0.6312**	**0.6535**	**0.6564**	0.1162	**0.0430**	0.1049	0.1049	0.2069	0.0705	0.1330	0.1330
Luhn	0.1473	0.0391	0.1023	0.1094	0.1202	0.0381	0.0789	0.1037	0.0678	0.0	0.0678	0.0678
KL-Sum	0.0800	0.0032	0.0567	0.0699	0.0541	0.0129	0.0445	0.0477	0.0694	0.0	0.0694	0.0694
Edmundson	**0.6593**	**0.6312**	**0.6535**	**0.6564**	0.1162	**0.0430**	0.1049	0.1049	0.2069	0.0705	0.1330	0.1330
Graph Reduction	0.4018	0.3229	0.3722	0.3797	**0.1553**	0.0212	**0.1221**	**0.1286**	0.1908	0.0824	0.1479	0.1479

the syntactic structure of the source text (position of words in the sentence, number of words, etc.), something that was better captured by these algorithms in Lawsuit Decision - Easy.

The Word Frequency algorithm also obtained a better F-score for all Rouge metrics compared to the other summary algorithms for Lawsuit Decision - Hard document. However, the TextRank and Graph Reduction algorithms obtained the best F-scores in Rouge-1, Rouge-L and Rouge-SE for Lawsuit Decision - Medium. But for Rouge-2, the LSA and Edmundson algorithms had the best F-scores for this document.

The use of Rouge metrics in this work is to show that the summarization algorithms used in the proposed tool can be useful to bring the most relevant information from a legal document. However, the F-score results are not high, which is to be expected given the nature of the reference summaries used. These summaries were generated with the aim of obtaining sentences that would facilitate the identification of repetitive themes and not to summarize the most important information in the source text.

5 Conclusion

Automatic Text Summarization has several advantages, including time-saving, instant response, and enhanced productivity. It has gained popularity across diverse fields, offering professionals an efficient means to achieve greater efficiency and accuracy in their work. Our tool, *LegalSum*, specifically supports summarization in the legal domain in Portuguese and was tested with lawsuits from the Sao Paulo Justice Court, the world's largest court [20]. Despite advancements, challenges remain in identifying important information and selecting critical sentences. With various expression forms, human language complexity poses difficulties for text summarization. Linguistic insights, while valuable, do not always determine the primary information for inclusion. Thus, further research is needed to develop more efficient methods addressing language complexity, information relevance, and context understanding. Automatic Text Summarization is valuable for processing vast amounts of information but requires ongoing development for efficiency and accuracy improvement. Enhancing text

summarization techniques allows professionals to quickly identify critical information, leading to better decision-making and productivity. Therefore, continuous research and development in this field are essential to meet modern information processing demands. In future work, we plan to enhance summarization quality by employing advanced techniques, including state-of-the-art classifiers based on Large Language Models. Specifically, we leverage language models tailored for Brazilian Portuguese, like BERTimbau [24] expecting to improve coherence, informativeness, and overall summary quality significantly. This approach will make our summarization system more adept at handling complex legal texts and the linguistic nuances of Brazilian Portuguese legal documents.

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The Use of Geographic Information Systems (GIS) in Guatemala for the Development of Risk Prevention Projects

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Abstract. Geographic Information Systems (GIS) have become invaluable tools in the development of risk prevention projects. These systems, through the integration of spatial data, the creation of hazard maps and the use of predictive models, simplify the identification of high-risk areas and contribute to the development of proactive strategies to prevent disasters. This article compiles geographic information from Guatemala provided by a Municipality project using LIDAR technology, which involves a laser scanner mounted on a drone to generate a three-dimensional model of the landscape. This technology represents the most detailed and accurate method for the creation of digital elevation models, replacing photogrammetry. The results show that there are some risks in Guatemala City and that it is important to take actions to avoid disasters affecting the study areas. The geographic complexity and susceptibility to various hazards in the region emphasize the importance of using GIS for informed decision making.

Keywords: GIS · LIDAR · UAV · Drone · Susceptible · Mitigating · Mapping · Risk prevention

1 Introduction

A Geographic Information System (GIS) is a tool used for the collection, storage, processing, and visualization of geographic information. GIS uses basic elements such as points, lines, and polygons to represent geographic entities and measurable and georeferenced spatial variables, based on established equations, according to the required study. The effective management of natural hazards is a major challenge in many parts of the world, and Guatemala is no exception. This beautiful Central American country is exposed to a wide range of natural hazards, such as earthquakes, volcanic eruptions, floods, and landslides, which pose a constant threat to its population and sustainable development [1].

Guatemala has experienced a series of notable weather-related events in recent years, which highlight the impact of changing weather patterns. These events include frequent sinkholes, flash floods, and rivers exceeding their normal capacity, each varying in size,

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damage, human and material losses. The identified causes for these occurrences are linked to insufficient maintenance of the drainage system, soil erosion caused by significant pumice deposits, or subterranean water flows. These erosion factors, combined with the continuous population growth, leading to increased construction activities in specific areas, as well as the rise in vehicular traffic, underscore the complexity of the issue. The absence of adequate soil studies during civil construction projects also plays a significant role. For example, in 2015, a major landslide occurred in an area known as El Cambray II, where the exact number of residents was unknown, underscoring the importance of implementing advanced geographical information systems. These systems aim to enhance risk management, community relocation strategies in high-risk zones, and overall territorial management to ensure more informed decision-making processes [2].

Institutions dedicated to disaster reduction often face challenges in generating adequate data, conducting studies, or implementing actions based on geographic information. These challenges can be due to a lack of access to technology, a shortage of experts competent in the use of advanced technologies like GIS, and high costs associated with data capture and processing. However, the implementation of GIS can help in expanding the way to manage risks, the relocation of communities at risk, and better territorial management. GIS provides valuable tools and technologies for collecting, analyzing, and visualizing geospatial data. It can help identify disasters before they occur, create an emergency database for people in need of assistance, forecast climate conditions, and help emergency managers resolve natural disaster challenges using the Comprehensive Emergency Management (CEM) approach. By incorporating GIS into the disaster response framework, planning, response times, collaboration, and communication during the most challenging dynamic circumstances can be improved. Developments in GIS have provided agencies with the ability to collaborate more efficiently and effectively [3].

The purpose of this article is to provide an updated view of geographic information in Guatemala, using data from existing projects, municipal information, and results from UAV missions conducted by the authors of this study. The central objective is to compile accurate and consistent data using LIDAR technology that offers an alternative for mapping risk areas in Guatemala. It also proposes the creation, dissemination and application of interactive map-based products that benefit various organizations, providing valuable geographic information for more effective decision making in risk management.

2 Background

Guatemala is currently facing a major challenge due to the absence of updated and complete geographic information, crucial for effective land use planning and to address the various risks facing the nation. Existing data, last updated in 2008, underscores the urgent need to manage up-to-date, high-quality information in GIS systems. The lack of such updated data poses a critical problem: the absence of a risk mitigation plan for communities most vulnerable to natural disasters and the inability to plan for their future relocation. This problem is compounded by the country's susceptibility to a wide range of events, including earthquakes, volcanoes, hurricanes, floods and landslides, with high frequency, low impact events and low frequency, high impact events. Surprisingly,

Guatemala is among the top five countries most affected by floods, hurricanes, and earthquakes, with more than 40% of its population simultaneously exposed to five or more hazards. In addition, the country has witnessed major events in the past, such as the El Cambray II landslide in 2015, in which the exact number of residents is unknown. Figure 1 shows the geographical area in which the disaster occurred [4].

Fig. 1. The Greater Metropolitan Area of Guatemala City and the area of the disaster.

Having a risk mitigation plan in the prevention projects would have been fundamental to prevent a possible relocation of both communities in the future and avoid tragedies in the long term. The demands of disaster risk management are such that concise, clear and reliable information is crucial. The information presented in Fig. 2 provides an overview of the frequency, impact and occurrence of natural hazards in Guatemala [5].

The main challenge lies in the absence of policies that promote the dissemination and implementation of GIS in the institutions responsible for disaster planning and management in the country. An equally significant problem is the lack of a policy aimed at collecting geographic data to feed the GIS and make it available for processing by institutions and professionals, which would be essential for effective decision making.

Currently, many municipalities and institutions, both in the public and private sectors, have access to GIS tools. However, the extensive use of these tools has not yet reached their full potential. The proliferation of software such as Quantum GIS and GVSIG has facilitated access to these technologies by government institutions, which has boosted the implementation of various projects, including those related to disaster management. A common denominator among these institutions and professionals working with GIS is the insufficiency of data, which in many cases is non-existent or does not meet the necessary quality standards.

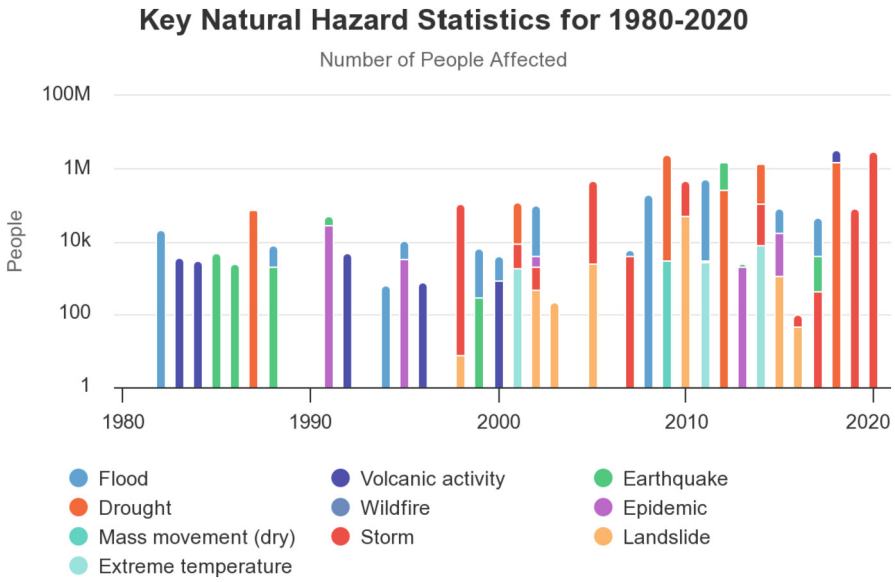

Fig. 2. Overview of the most frequent natural disaster in Guatemala.

3 Methodology

The methodology of this study was based on a combination of documentary data sources and field data collection. The main one is a USAID project that has funded several geographic projects in Guatemala to improve urban governance. In 2021, USAID provided funds to upgrade seven municipalities in Guatemala's metropolitan area, covering a total of 568.91 km^2 [7] (See Fig. 3).

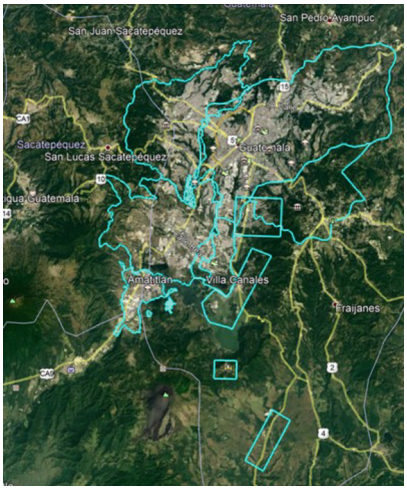

Fig. 3. Zones updated by the USAID project.

The critical geographic information to carry out the risk analysis was acquired through the use of specialized equipment with the following characteristics (Table 1):

Table 1. Equipment used in the research (GF Consulting S.A)

Parameter	Description
Precision	Submetric
LIDAR ppm (points per m^2)	+4
Images (GSD)	±10 cm urban areas, ±50 cm rural areas
Countours	Countours 1 m urban areas, +5 m rural areas
Digital Terrain Model (DTM)	1 m

4 Results and Discussion

In this case, the LiDAR data allowed the generation of digital terrain models (DTM) with sufficient accuracy to carry out flood, landslide and slope related studies. This included the possibility of generating contour lines with a 1-m standard. In addition, aerial imagery captured with a pixel size of 10 cm (GSD) facilitated the visualization of relevant features for various analyses. Also, these images were used to create digital cartography at a scale of 1:1,000, which was especially useful in urban contexts, allowing the generation of information layers covering urban inventories, land cover features, buildings, street, and bridge infrastructure, as well as hydrographic details of the region. The Fig. 4 shows an example (Fig. 5).

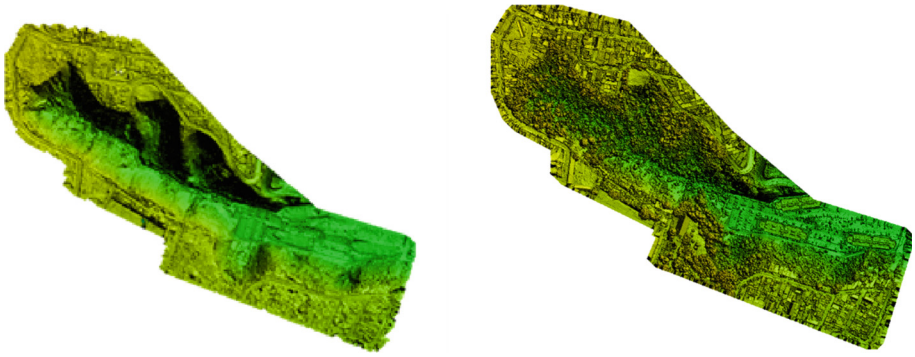

Fig. 4. Digital terrain and surface models in the municipality of Villa Nueva (Guatemala). (GF Consulting S.A)

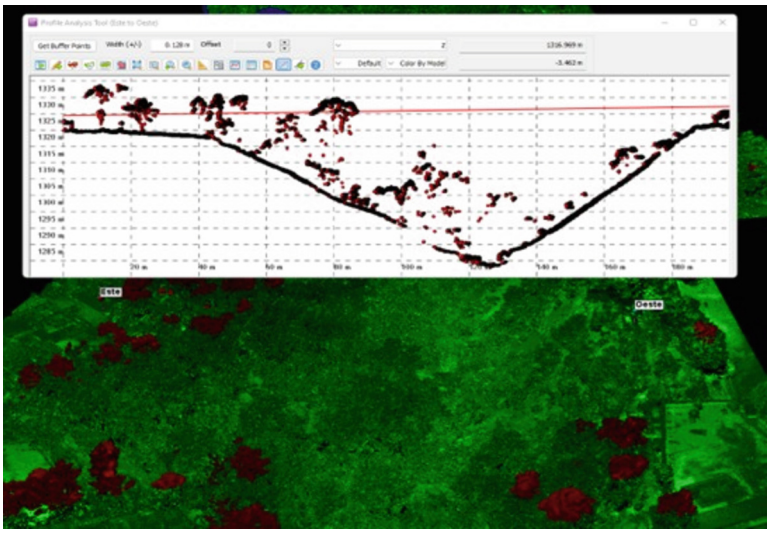

Fig. 5. Cross section of LiDAR point cloud for risk analysis, municipality of Villa Nueva (Guatemala). (GF Consulting S.A)

For data to be useful for risk studies and similar applications, it should at least meet a standard in formats and quality of information. This standardization should have the following characteristics (Table 2):

Table 2. Data extracted and consulted with the equipment of the company (GF Consulting S.A) Guatemala:

Parameter	Description
Lidar data	LAS v1.0 (minimum)
Images	GEOTIFF, ECW or similar
Countours	DWG, Shapefile or similar
Digital Terrain Model (DTM)	Ascii, GEOTIFF

To keep the geographical database updated of any institution related to risk analysis, captures should be carried out every two years. This will guarantee having useful geographical data especially in places such as rivers, bodies of water and volcanoes. Currently in Guatemala only a few municipalities have updated LiDAR information and aerial photographs. Some other municipalities have made efforts to carry out drone flights of some areas of their municipalities, as shows the Table 3.

Table 3. Data extracted and consulted with the equipment of the company (GF Consulting S.A) Guatemala:

Country List					
Municipality	Area	Covered Area	Rural/Urban	Type of data	Capture date
Antigua Guatemala	78 km^2	63 km	Urban	LIDAR + aerial images	2020–2021
Palín	92.2 km^2	45.9 km^2	Urban	LIDAR + aerial images	2022
La Gomera	492 km^2	11 km^2	Urban	LIDAR + aerial images	2020–2021
Chinautla	67.053	44 km^2	Urban	LIDAR + aerial images	2020–2021
Guatemala	215.04	218.91 km^2	Urban	LIDAR + aerial images	2020–2021
Mixco	90.326	103.50 km^2	Urban	LIDAR + aerial images	2020–2021
Santa Catarina Pinula	67.351	50 km^2	Urban	LIDAR + aerial images	2020–2021
Villa Canales	280.02	57 km^2	Urban	LIDAR + aerial images	2020–2021
Amatitlán	100.97	18 km^2	Urban	LIDAR + aerial images	2020–2021
Villa Nueva	89.068	95 km^2	Urban	LIDAR + aerial images	2020–2021
San Miguel Petapa	23.798	26.50 km^2	Urban	LIDAR + aerial images	2020–2021
Ciudad Vieja	68.395	11 km^2	Urban	LIDAR + aerial images	2020–2021

Note: The difference between the areas (according to IGN) and the covered areas is because the municipalities differ from these limits. Some municipalities have litigation over boundary issues

5 Conclusions

The implementation of a Geographic Information System (GIS) in Guatemala for risk mitigation proves to be a highly effective and promising strategy. Through the utilization of geospatial technology and regularly updated data, GIS offers a comprehensive understanding of the various risks within the Guatemalan territory, facilitating well-informed decision-making for more efficient disaster planning and management. The numerous advantages provided by GIS, including real-time integration and analysis of geographic data, the identification of high vulnerability areas, the visualization of patterns and trends, and the effective communication of pertinent information to stakeholders, empower relevant disaster management authorities and agencies to anticipate

risk situations, proactively implement preventive measures, and coordinate response actions with greater efficiency. The use of Lidar technology is and will continue to be of paramount importance for conducting risk mitigation processes, not only in Guatemala but also globally.

The application of this technology has the potential to improve decision making in a wide range of areas beyond risk mitigation. Further efforts to refine the system will be critical to ensure its effectiveness as a valuable tool for the sustainable development of the country. A critical aspect is the continuous improvement of the collection, cleaning and maintenance of Guatemala's geospatial information. Equally important is the comprehensive training of GIS users in Guatemala to maximize the usefulness of the system. In addition, it is imperative to raise public awareness of the benefits of GIS and its impact on informed decision making. These collective efforts will contribute significantly to disaster mitigation planning, including the relocation of vulnerable communities.

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Information Technologies in Education

Understanding Academic Anxiety in the Digital Age: An Exploratory Analysis Among University Students and the Influence of New Technologies

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Abstract. The problem of academic anxiety is a recurrent issue among university students. Therefore, this study seeks to analyze the Ecuadorian context regarding the perception that students have about exam anxiety, mitigation methods, and its relationship with their academic performance. A total of 1274 students (M = 630, F = 644) from the three largest cities in the country, from multiple majors and semesters, were surveyed to determine their respective correlations. The significant findings demonstrate that, indeed, the sensation of anxiety produced by exams is more linked to women than to men, and also depends on the major and semester they are in. On the other hand, regarding anxiety mitigation, although there is no correlation with gender, major, or semester, it is evident that non-pharmacological options such as deep breathing, exercise, and meditation are the most common. Finally, academic digital performance with anxiety only has a significant correlation with the semester. In conclusion, it has been shown that academic anxiety produced by exams and academic performance is a common multifactorial complex phenomenon in Ecuador that needs to be ad-dressed consistently with strategies that enhance the well-being of students in higher education institutions.

Keywords: Academic Anxiety · Ecuador · Higher Education · Students · Evaluation · New Technologies

1 Introduction

School performance is related to the student's abilities and skills to perform in a specific area of knowledge. Several elements, such as motivation, self-efficacy, and academic self-perception, are integrated to achieve good school performance. The absence or alteration of any of these elements deteriorates school performance causing anxiety, which negatively influences learning because it affects concentration, attention, and memory [1]. Students with high anxiety levels show symptoms of embarrassment, shyness, sleep disturbances, behavioral changes, insecurity, and excessive preoccupation with academic issues such as evaluation [2, 3].

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Anxiety regarding academic performance has not been sufficiently studied in the academic environment. That is why the need arises to implement strategies and tools to emotionally address university students who have anxiety problems by adopting appropriate teaching methods and taking actions to prevent students from considering themselves incapable of performing and fulfilling their tasks and even to prevent them from dropping out of the educational institution. Considering this scenario, we pose some questions to analyze this situation in the university environment.

1. To what extent are the effects of anxiety associated with academic performance?
2. In which gender and major is anxiety most frequently evidenced?
3. What actions can be taken to prevent anxiety?
4. How practical is applying pharmacological and non-pharmacological measures to cope with and treat anxiety problems?
5. Are there reasons that trigger anxiety in students?
6. What are the symptoms of college students with anxiety?

2 Theoretical Framework

Anxiety is a pathology characterized by constant worries and fears in the individual caused by actual or unreal events. Anxiety is common in people between 14 and 65 years of age and is produced as a response to a threat or an unpleasant situation [4]. Epidemiological studies in Ecuador show that 4 out of 10 people, mainly young adults and women, suffer from anxiety disorders [5]. According to the analyses, most anxiety disorders are more frequent in women and people between 25 and 34 years of age with a low educational level. Some factors that can provoke anxiety are living alone, unemployment, and having experienced some trauma [6, 7]. These patients may have palpitations, excessive sweating, difficulty swallowing, dyspnea, increased respiratory rate, gastric discomfort, stuttering, hyperactivity, repetitive movements, and increased consumption of substances such as cigarettes or coffee [8].

In education, it was believed that low anxiety levels could increase intellectual engagement and even motivate students to improve their performance. However, different studies on this topic have shown that anxiety disorders do not benefit students, so they should be treated to help students define the importance of each task and have a positive attitude [9].

Education is the only way to achieve the fullness of skills [10, 11]. For this reason, teachers must develop adequate didactics to approach and teach students, positively influencing their learning [12]. Neuro-didactics allows the teacher to understand how the brain works to keep students focused on the content being taught through electrical brain stimulation, generating emotions and interactions that promote learning [13, 14]. Academic anxiety is an emotional response of cognitive, motor, and physiological reactions to academic situations that may seem dangerous or threatening to students. Academic anxiety can be caused by changes in daily routine, activities, assessments, or meeting new people, and its effects can cause inhibition of learning and performance of complex tasks. Another element related to anxiety is self-efficacy because low grades and a lack of confidence to face academic challenges can cause anxiety disorders in students [15–17]. Anxiety negatively influences learning as it decreases concentration, information

processing, and attention, causing the student to feel low self-esteem, insecurity, and shyness [18–21]. To address anxiety disorders in students, alternative teaching strategies adapted to the teacher's educational needs and planned assessments that consider the characteristics of the students should be used.

University education should focus not only on academic training and summative evaluation based on grades but also on the emotional state of students. The results of this research show the need to implement measures to detect and treat anxiety to achieve the integral formation of students, focusing the evaluation on the criteria of a formative and diagnostic model.

3 Materials and Methods

This research aims to analyze university students' perceptions of anxiety and the learning process when taking their exams or tests. For this purpose, a quantitative study was conducted with two specific objectives: 1. to examine the connection between anxiety and university exams, 2. to identify alternatives to decrease the anxiety provoked by exams. From this, we posed the null hypothesis H0: There is no significant relationship between students' anxiety and university exams, deriving the following alternative hypotheses:

H1: Gender, major, and semester of university students significantly influence the perception of anxiety caused by summative evaluation.

In elementary education, there is a tendency for anxiety levels to increase when taking exams as the course progresses [22]. The demands of higher levels of schooling provoke more anxiety in students. Gender is also related to anxiety, as evidenced by the difference between anxiety disorders experienced by males and females [23]. Regarding the university major, some studies show that specific professions, such as Nursing [24] or Dentistry [25], are highly connected with anxiety. Other studies associate anxiety with clinical disorders like depression or stress [26]. Some bibliographic references address anxiety as a primary variable but only in countries such as Saudi Arabia [27], Malaysia [28], and the United States [29]. Because of this, we intend to perform a similar analysis of anxiety related to gender, major, and semester in the Ecuadorian university context.

H2: There is a significant relationship between gender, major, and semester of college students and their perception of anxiety mitigation in learning assessment processes.

The academic literature shows that most of the research on the perception of anxiety in learning assessment processes was conjunctural to the issue of the pandemic and online learning [30, 31], and [32]. According to the literature review, some studies focus on foreign language learning [33, 34]. It can be stated that academic performance is directly related to anxiety [35]. Therefore, considering that the post-pandemic context has modified learning processes, it can be noted that there are no previous studies that sup-port the direct relationship between anxiety mitigation and learning assessment processes.

H3: The gender, major, and semester of university students are related to their perception of the relationship between anxiety and academic performance.

Academic performance is directly related to anxiety [36]. Some studies state that low anxiety levels can improve academic performance and increase motivation [37]. High anxiety levels can have the opposite effect, decreasing academic performance [38]. Some

studies show that anxiety is also related to gender [38], but its possible relationship with the major or the semester is unknown.

This research has a descriptive-mixed scope defined as measuring the characteristics or variables of a phenomenon or group of individuals without intervention [39]. For this purpose, a survey was elaborated with 17 questions, 13 closed and 4 open, divided into 3 sections: 4 on sociodemographic data, 8 on anxiety, and 5 on the learning process.

The survey was validated by 7 experts with more than 5 years of experience in Education and Psychology at the Universidad Politécnica Salesiana, Ecuador, Universidad del Azuay, Ecuador, Universidad de Cuenca, Ecuador and Universidad Rey Juan Carlos, Spain. These experts suggested changing the wording of the items, delimiting the con-structs of anxiety, performance, and learning, and revising the response options in 4 questions. The questionnaire was then administered to a sample of 34 students to assess the quality of comprehension of the questions. The number of questions was reduced from 20 to 17, thus reducing the time to answer the questionnaire. At the statistical level, the reliability index of the questions was calculated, obtaining a value of 0.7403 which shows the high reliability of the data collection instrument.

The final version of the survey was applied to a non-probabilistic random sample of 1274 higher education students (M = 630 and F = 644) in Ecuador's three most important cities: Quito, Cuenca, and Guayaquil. The surveyed students study one of the following 25 majors: Business Administration, Architecture, Anthropology, Biomedicine, Biotechnology, Computer Science, Accounting and Auditing, Law, Local Development, Multimedia Design, Education, Economics, Basic Education, Initial Education, Intercultural Bilingual Education, Electricity, Electronics and Automation, Nursing, Environmental Engineering, Automotive Engineering, Civil Engineering, Industrial Engineering, Mechatronics, Digital Business, Physical Activity and Sports Pedagogy, Psychology, Telecommunications, and Theology. The questionnaire was applied from January 18 to March 5, 2023, and the data generated were coded and articulated through SPSS v.29 software to facilitate the interpretation of the data mentioned in the specific objectives. Depending on the variables, Pearson's coefficient and chi-square analysis were performed in the study.

4 Results

4.1 The Gender, Major, and Semester of College Students Significantly Influence the Perception of Anxiety Caused by Summative Evaluations

To address this hypothesis, the relationship between anxiety and university exams was analyzed, considering the perception of the students surveyed. For this purpose, a linear correlation was established between the independent variables: gender, major, and semester, and the dependent variables: feeling anxiety during exams and emotional or physiological changes when hearing the word "exam" or when taking tests or exams.

There is a statistically significant relationship between anxiety perception and gender, with a Pearson's coefficient of −0.115 and sig. (bilateral) of 0.000037. The negative correlation implies that, on average, women experience more anxiety caused by exams than men. However, the correlation could be stronger, suggesting that there is not much of a relationship between these two variables. The value of the sig. (bilateral) is low,

indicating that the probability of obtaining a correlation as strong or stronger than that observed by chance is very low. Therefore, it is concluded that the correlation is statistically significant and that the relationship between gender and anxiety caused by exams is very likely to be non-random (Table 1).

On the other hand, the Pearson correlation of −0.056* and a sig. (bilateral) of 0.044 between major and anxiety caused by exams indicates a weak but statistically significant negative correlation between these two variables. The negative correlation implies that, on average, people studying specific majors may experience less distress during exams than those studying other majors. However, the strength of the correlation is weak, suggesting that there is not much of a relationship between these two variables. The value of the sig. (bilateral) is low, so it is concluded that the correlation is statistically significant and that the observed relationship between major and distress during exam times is probably real (Table 1). Specifically, Intercultural Bilingual Education, Mechatronics, Biotechnology, Accounting and Auditing, Civil Engineering and Telecommunications are the majors in which it demonstrates the highest perception of anxiety, while Electronics and Automation and Physical Activity and Sports Pedagogy are the least self-perceived anxiety by students.

The correlation between semester and anxiety caused by exams is 0.70, indicating a moderately strong positive relationship between the two variables. The sig. (bilateral) of 0.012 suggests that the probability of observing a correlation of at least 0.70 between semester and exam period distress by chance alone is very low. Therefore, the observed correlation is statistically significant, suggesting that the anxiety caused by exams increases as the semester progresses (Table 1).

It can be affirmed that there is a direct and statistically significant relationship between gender and anxiety during exams. Although the relationship decreases, it is still substantial concerning major and semester.

For the dependent variables: emotional or physiological changes when hearing the word “exam” or when taking exams, the Chi-Square calculation was used since these were dichotomous option responses, showing that there is a correlation with gender ($p = 0.002$) but not with major ($p = 0.385$) or semester ($p = 0.419$). These two questions, “Do you notice any emotional or physiological change when you hear the word “exam” in the teaching-learning process?” and “Do you notice any emotional or physiological change when you take exams or tests? “ are statistically significant only for gender.

Analyzing the gender data, 498 (77.3%) female students and 440 (69.8%) male students noticed an emotional or physiological change when they heard the word “exam” and 522 (81%) female students and 465 (73.8%) male students noticed an emotional or physiological change when they took exams. The most frequent manifestations are palpitations (48.7%), increased or decreased appetite (47.4%), loss of sleep (46.8%), sweating (39%), empty stomach (32%), need to go to the bathroom (31.5%), desire to smoke (9.4%) and desire to drink alcohol (4.8%).

Table 1. Pearson correlation between anxiety caused by exams and gender, major, and semester.

Gender		
		Do you commonly experience anxiety or other manifestations or disturbances during university exams?
2. Gender	Pearson correlation	−,115**
	Sig. (bilateral)	<,001
	N	1274
**. Correlation is significant at the 0.01 level (bilateral)		
Major		
		Do you commonly experience anxiety or other manifestations or disturbances during university exams?
3. Major	Pearson correlation	−,056*
	Sig. (bilateral)	,044
	N	1274
*. Correlation is significant at the 0.05 level (bilateral)		
Semester		
		Do you commonly experience anxiety or other manifestations or disturbances during university exams?
Semester	Pearson correlation	,070*
	Sig. (bilateral)	,012
	N	1274
*. Correlation is significant at the 0.05 level (bilateral)		

4.2 Gender, Major, and Semester of College Students and Their Perception of Anxiety Mitigation in Learning Assessment Processes

Analyzing the Chi-square calculation, the data show that there is no significant correlation between gender ($p = 0.638$), major ($p = 0.137$), and semester ($p = 0{,}735$) with the routines or processes to reduce anxiety caused by exams or tests. It is proven that 813 students (63.8%) do not perform activities to reduce academic stress, while 461 students (36.2%) do. Some activities that students prioritize to mitigate anxiety are deep breathing (304 students), pharmacological prescription (88 students), exercise (41 students), and Yoga/meditation (28 students) (Fig. 1).

When asked about the benefits of teacher participation and the implementation of academic strategies to reduce anxiety, there were 90.7% positive and 9.3% negative responses. With the teacher's involvement and help, students could know the specific topics they need to study, clarify their doubts, and feel more confident to take the exam. The teacher's help and guidance would reinforce learning, psychologically prepare students to take their evaluations, enhance feedback, and synthesize and summarize the results.

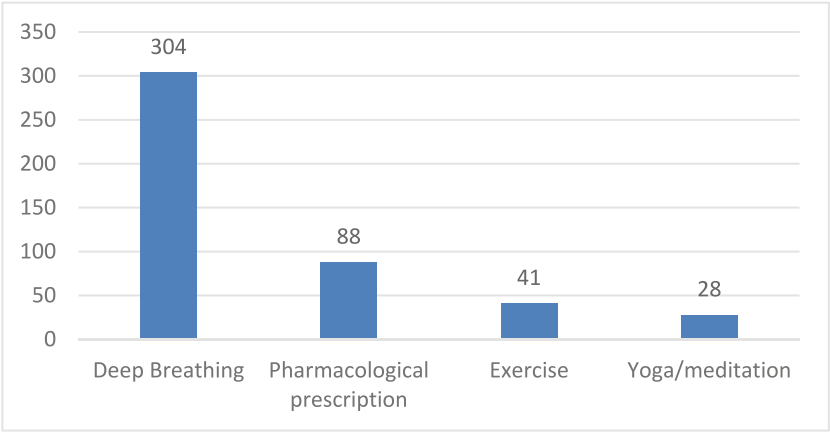

Fig. 1. Mitigation of anxiety among students

4.3 Gender, Major, and Semester of College Students and Their Perception of the Relationship Between Anxiety and Their Academic Performance

The correlation between the proposed sociodemographic data and the questions related to academic performance was reviewed. Pearson's coefficient analysis showed that only the semester is statistically significant within this section of questions. On the other hand, there was no direct correlation between gender and major with anxiety in the learning process. However, it is correlated statistically significant with semester.

The analysis of the correlation between semester and the effect of anxiety on academic performance showed that 47.3% (602 students) responded "almost always" or "always." The highest values were obtained in the 10th semester with 53.7%, the 9th semester with 52.4%, and the 7th semester with 51.3%. The lowest values were obtained in the 1st semester with 40.2%, the 2nd semester with 40.4%, and the 3rd semester with 46.3%. This is why we can conclude that the perception of the effect of anxiety on academic performance is higher in the last semesters and lower in the first semesters.

5 Conclusions

This study's results show a significant correlation between exams and anxiety because anxiety levels are higher during academic evaluations [40]. As corroborated by previous studies, women experience these disorders with greater intensity and frequency [41], same as has been demonstrated in this study, women perceived more anxiety on the learning experience caused by exams than men.

Also, Students from Intercultural Bilingual Education, Mechatronics, Biotechnology, Accounting and Auditing, Civil Engineering and Telecommunications majors from Ecuador are more prone to anxiety as they advance through the professional formative levels, showing that although there is a certain tendency to evidence that anxiety is more oriented to technical majors [42], the results showed that other majors more oriented

to social sciences can also be perceived as anxious by students. in which the following are added based on other variables that could be explored in further studies as the accumulation of tasks and the rigorousness of pre-professional learning practices.

Regarding the hypothesis about the semester and their perception of anxiety [22], it is indeed evident that students perceive greater anxiety as they climb levels in the major. As the semester progresses, the self-perception of anxiety is gradually becoming higher.

As for the second hypothesis, it is rejected because that there are no previous studies in the scientific literature that relate anxiety mitigation in college students, the results of this study showed that there is no direct relationship between the ways of mitigating anxiety with gender, major or semester, this implies that the strategies used by young people to mitigate the effect of anxiety are general and are applied by all without a determination of their profile, these strategies are deep breathing, pharmacological prescription, physical exercise and yoga/meditation.

Taking into consideration the third hypothesis raised about the perception that students have about anxiety and their academic performance, it has been shown in previous studies that there is a relationship with gender [38], but there is no information about major or semester. However, when reviewing the data obtained in this study, it was shown that there is no relationship between anxiety produced by academic performance and anxiety with gender or major, but there is a significant relationship with the semester, demonstrating that when the semester increases, it is perceived that it can affect anxiety in academic performance.

Academic anxiety is a complex and multifactorial phenomenon influenced not only by the "exam" variable but also by various aspects of personality and the context in which students develop.

The results also suggest that personality, previous experience in taking academic tests, and even family and social pressure are relevant aspects to consider when discussing academic anxiety. The economic situation of low-income students is another factor since this is crucial for them to continue their studies and often to have access to student scholarships [43].

This research could be very beneficial for educators and health personnel to determine the factors associated with education and emotions to implement strategies that favor school performance during evaluation periods. It is worth noting that in some cases, the simple fact of hearing the word exam immediately causes mental alterations and emotional and physiological changes in students [44].

It is worth mentioning that we faced some obstacles during the research was the time it took us to apply the surveys and the fact that the anxiety issue can be subjective considering the participants' self-perception.

University teachers are fundamental in the teaching-learning process, so they must implement methods and strategies to strengthen student learning. Teachers and professionals working in the student wellness and health departments need to be aware of the effects of academic anxiety to work together for students' well-being and mental health.

It is recommended that teachers reinforce the content to be evaluated in the exams, provide feedback (tutorials), and design evaluation rubrics. These actions improve the evaluation process and academic performance and reduce uncertainty, thus reducing academic anxiety in students. It is also recommended that students study and prepare

academically and psychologically to perform complex tasks and take school tests and exams with optimism and confidence.

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Contributes of the Integration Between Computational Thinking and Artificial Intelligence for Mathematics Education

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Abstract. Actually, in education, the synergy between Computational Thinking and Artificial Intelligence has emerged as a transformative force with implications in Mathematical Education. This paper aim to explore the dynamic interplay between CT and AI and their collective contributions to enhancing the pedagogical impact on mathematical education. By harnessing AI-powered tools and methodologies, educators can personalize learning experiences, adapt instructional sequences, and offer real-time feedback tailored to individual student needs. The integration of CT and AI also empowers learners to approach mathematical challenges with algorithmic problem-solving skills, fostering a deeper understanding of mathematical concepts. Through a comprehensive analysis of existing literature and practical examples, this paper showcases how the amalgamation of CT and AI can cultivate a more engaging and effective mathematical learning environment. Given the age of AI, CT is a crucial skill for students to develop, and the guidance of a qualified teacher is essential. The challenge lies in regulating the use of AI in contexts where regulation is insufficient, particularly in projects that evade adherence to robust ethical standards or community-defined rules. It is hoped that this study demonstrates the potential to bridge the gap between theoretical knowledge and practical application, equipping teachers, and students with the necessary skills to navigate the complexity of an AI-driven world, in a context of mathematics education.

Keywords: Computational Thinking · Artificial Intelligence · Mathematical Education

1 Introduction

The UNESCO report [27], titled “Technology in Education: A Tool on Whose Terms?”, draws attention to the following key points: the integration of digital technology has led to significant changes in education and learning. However, ongoing debates persist

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about whether technology has truly revolutionized education, as proponents often claim. The utilization of digital technology varies across communities, socioeconomic levels, teacher readiness, education levels, and country incomes. Except for the most technologically advanced nations, the widespread use of computers and devices in classrooms remains uncommon. Furthermore, the impact of technology remains uncertain and varied. The actual short- and long-term costs of digital technology usage appear to be significantly underestimated. Often, those who are most disadvantaged lack opportunities to benefit from it. By posing the question "A tool on whose terms?", the report highlights that regulations imposed on technology from outside the education sector may not necessarily address the needs of education. Accompanying the report is the #TechOnOurTerms campaign, advocating for technology decisions in education to prioritize learners' needs after evaluating whether its application is suitable, fair, evidence-based, and sustainable.

The report underscores the importance of developing the ability to live both with and without digital technology. However, the central focus should remain on learning outcomes rather than the mere use of these technologies. To enhance learning, digital technology should not serve as a substitute but rather as a complement to in-person interactions with teachers. The report also emphasizes the significance of achieving a healthy balance between life with and without digital technology. It emphasizes that the primary concern should revolve around learning outcomes, specifically the effective development of students' skills and knowledge, rather than solely concentrating on the utilization of the technologies themselves.

While digital technology is considered a valuable tool for enhancing learning, the report emphasizes that it should not entirely replace in-person interactions with teachers. Instead, it should be viewed as a supplementary resource to traditional teaching, enriching educational opportunities and making them more diverse and comprehensive.

This perspective suggests that the use of technology should be deliberate and carefully planned, considering how it can best integrate into the teaching and learning process to enhance students' educational experiences. Additionally, the report underscores the importance of developing adaptation skills to navigate technological changes, empowering students to address the challenges of the modern world.

1.1 AI and Education

The lines between the roles of teachers and computers in education have been debated for decades, using terms like "computer-aided instruction," "blended instruction," and "personalized learning." However, Cardona, Rodrígez and Ishmael [10] raises the question of how instructional decisions are made in systems involving both humans and algorithms. With the advancement of Artificial Intelligence (AI) systems and tools, the discussion on using AI in classroom pedagogy and student learning will intensify. As emphasized by the authors, AI systems and tools are already enabling instructional sequences to adapt according to student needs, providing feedback and hints, especially in scenarios like solving math problems or learning foreign languages.

Thus, the presence of AI in education is promising, offering personalized learning experiences tailored to individual learning paces and styles. By adjusting instructional sequences based on student performance and progress, AI can provide a more efficient and effective learning support.

It's worth noting that, to enhance AI understanding, Long and Magerko [18] introduced the concept of AI literacy - a skill set enabling critical assessment of AI technologies, effective communication and collaboration with AI, and the utilization of AI as a tool across online, home, and work contexts. Integrating AI literacy into K-12 curricula is crucial for educators, as it prepares students for a technology-driven world. Strategies include introducing AI concepts early, integrating AI into existing subjects, providing hands-on experiences, fostering critical thinking skills, incorporating real-world AI examples, and offering resources and training for effective AI education [18].

Furthermore, it's essential to perceive AI not as a complete substitute for teachers but rather as a supporting tool to complement and enhance the learning experience. The guidance and presence of a teacher remain crucial for students' educational success.

1.2 Computational Thinking and Education

Computational Thinking (CT) refers to the thought processes involved in formulating problems so that their solutions can be represented as computational steps and algorithms. It involves ideas like abstraction, data representation, and logical organization of data, which are also prevalent in other types of thinking, such as scientific thinking, engineering thinking, systems thinking, design thinking, and model-based thinking [28].

The official curriculum documents in Brazil, [9], views CT skills as essential for mathematical reasoning, problem-solving, and communication. These skills are nurtured through activities like problem-solving, investigation, project development, and modelling across all levels of basic education. In Portugal, the reason for the inclusion of CT in the Mathematics curriculum is debated. Information Technologies and Communication teachers claim that it is a subject they should deal with, taking time away from the subject of Mathematics. However, the designers of the mathematics curriculum in Portugal claim that CT is a way of solving problems, i.e., it should be used in Mathematics classes. In fact, this discussion takes place in numerous countries among professionals in Computer Science and Mathematics [26]. The development of CT in the mathematics curriculum is one way to implement the European Union (EU) strategies related to digital competencies. This issue is a reality in Finland and Portugal, and all EU members point to CT to develop problem-solving and logical thinking skills [8].

A study by Abar et al. [1] presents proposals created by participants of a project on CT in the basic school within a remote context, involving ten teachers from basic and higher education schools in Brazil, Portugal, Cape Verde, and Angola. With support from a constructivist framework and the theory of activity, these teachers underwent training for their teaching performance in the context of CT and evaluated the impact of their understanding on various dimensions. The introduction of concepts and practices of CT, as indicated in the literature, effectively contributed to the development of significant proposals on the subject and had positive effects on the application of some of them not only in the context of mathematics but also in other areas of the sciences. The project's development provided substantial insights into how the participants positioned themselves regarding the understanding of CT and how they integrated it into the tasks they created.

1.3 AI Literacy and Computational Thinking

The emerging knowledge gained from the relationships between the use of technologies, AI, and cognitive sciences may hold the most powerful potential to change some of the current paradigms of education. The realization of these goals implies a vast database of tasks created by teachers, adaptable to various student learning styles, utilizing the teacher's comprehensive understanding of difficulties, errors, and students' misconceptions. Automatic feedback tasks enable the creation of supervised learning processes, incorporating external feedback that can be seamlessly integrated into an automatic tutor system (ATS). The collaborative nature of these tasks is an essential requirement for delivering feedback that facilitates user learning. The development of an ATS has clearly proven beneficial, and each task requires analysis by multiple actors to provide quality feedback and encourage effective learning. Conversely, feedback leading to a regulatory assessment of the user's learning from tasks is more intricate, as it hinges on the heuristic approach considered during task preparation—an approach that necessarily encompasses the diverse paths users may undertake when faced with the proposed challenge [13].

AI literacy and CT are related, as both involve problem-solving skills and the ability to understand and use technology effectively [14]. CT is positively associated with AI literacy: "Individuals with higher computational thinking skills might be more familiar with AI concepts and recognize AI. Therefore, it is worth exploring the association of computational thinking with AI literacy" [11].

Hence, the development of CT skills can empower individuals, students, and teachers to become more AI literate and better equipped to understand and effectively use AI technologies. The challenge lies in implementing these concepts in school practice.

2 AI and Mathematics Education

Nowadays, CT, as a problem-solving approach, has a strong connection with Mathematics Education. CT can be utilized to foster literacy skills and is positively associated with mathematics learning [30]. Integrating CT into mathematics education can help students reinforce and improve their math skills, gain a deeper understanding of foundational concepts, and develop critical thinking and problem-solving skills [20, 25]. Thus, contributing to the development of AI literacy in Mathematics Education also entails fostering CT.

On the other hand, in the context of math problem-solving, AI can monitor the student's resolution process, identify difficulties or common errors, and provide immediate and specific feedback. This assists students in correcting their mistakes and enhancing their mathematical skills, potentially boosting their confidence and motivation to continue practicing and improving in math.

Some of the most common AI applications in mathematics education include grading software, where AI automates the grading process, providing quick and accurate feedback to students [24]; gamification, where AI creates gamified math programs that engage students and incentivize their learning [24]; Intelligent Tutoring Systems (ITS), where AI-powered tutoring systems offer personalized instruction and support to students, adapting to their individual needs and learning pace [29]; learning prediction: AI

algorithms analyze student data and predict their learning progress, allowing educators to tailor their instruction accordingly [29]; Adaptive Systems and personalization, where AI is used to create adaptive learning environments that adjust content and activities based on individual student needs and preferences [29]; robotics, where AI-powered robots enhance hands-on learning experiences and promote problem-solving skills in mathematics education.

Research in Mathematics Education highlights AI's role in teaching and learning the subject. In Mohamed [22], a systematic literature review on AI in mathematics education is conducted. Various databases were searched, articles were selected based on criteria, and quality was assessed. The review aims to comprehensively present AI's applications in math education for all student levels, aiming for personalized learning, improved outcomes, and enhanced teaching practices. AI can elevate teaching quality, adapt to individual student needs, motivate, and engage learners, foster critical thinking, provide access to advanced resources, optimize efficiency, and enhance accessibility. However, challenges exist, including a lack of empirical validation, theoretical gaps, the need for accessible AI, risks of perpetuating biases, and ethical concerns. The authors stress the importance of studying AI's effectiveness and its potential to enrich mathematical education, beyond just the influence of robotics [22].

Cardona, Rodríguez, & Ishmael [10, p. 15] highlight the increasing capabilities of AI tools in automating tasks and personalizing learning experiences. These tools adjust learning sequences, pace, hints, and trajectories. Future AI systems could aid students with homework, recommend teacher-favoured lesson plans, and support collaborative assignments. They could also assist teachers in classroom routines.

The development of AI tools' automated actions aligns with the advancement of personalization tools, which currently adapt learning experiences based on prior knowledge. Soon, AI may assist students with homework and offer teaching support, recommending lesson plans, and assisting with classroom routines. Integrating AI in collaborative student groups is also promising.

Ethical development of AI tools is crucial to prevent biases and discrimination. Balancing AI's supportive role with teachers' central role and providing proper training are essential. AI holds potential for education, supported by examples like AI-based math tutoring, adapting learning environments for special needs, and AI-assisted collaborative teamwork [10, p. 18]. These examples align with cognitive learning theories, the Universal Design for Learning, and Computer Supported Collaborative Learning, showcasing AI's potential to enhance teaching and learning in various educational contexts.

Examples of AI applications in mathematics education include studies by Kraishan [17] and Hwang et al. [15].

Kraishan's research explored effective features of integrating AI into the 8th-grade science curriculum in Oman. The study aimed to assess the efficacy of AI applications in education and the educational strategies underlying the science curriculum. Participants included 60 individuals responsible for selecting the 8th-grade textbook in Oman's public education schools. The results highlighted the effective role of AI in enhancing learning performance levels. There was a moderate improvement in teacher performance and a significant improvement in educational strategies, reflecting agreement among teachers regarding the application of AI in the 8th-grade science curriculum.

Hwang et al. [15] proposed an intelligent tutoring system to assist fifth-grade students in learning the math unit of multiplication and division. They found that the intelligent tutoring system (ITS) improved students' math learning performance and increased their motivation to learn. The study introduced an expert system approach, considering both the affective and cognitive states of each student. An adaptive learning system was implemented based on this approach in a fifth-grade math course to compare learning performances and student perceptions. Results revealed that the proposed approach aided low-performing students in successfully completing learning tasks. Conversely, those learning from the conventional cognitive factor-based approach were more likely to give up on tasks and relied more on the detailed version of instructional materials.

Richard et al. [23] curated a collection of AI research in Mathematics Education, conducted between 2018 and 2023. This collection presented various studies illustrating how AI can serve human mathematical learning. The research aims to explore AI's contribution to mathematics education, investigating its impact on teaching and learning. Objectives include assessing AI's role in mathematics education, promoting AI technology adoption among educators, and utilizing AI applications for seldom-addressed groups such as teachers and high school students. The study underscores AI's potential to enhance math education through personalized instruction, feedback, and support. Qualitative methods are highlighted for collecting learner feedback and analyzing perceptions. The findings suggest AI can improve problem-solving skills, conceptual understanding, and engagement in math. It further emphasizes AI's potential to create adaptive learning environments, personalized tutoring systems, and gamified math programs for diverse student needs [23].

3 AI and Teaching Training

The term CT offers a new approach in the field of cognitive science, by systematizing the steps of problem-solving that can be applied in AI and other sciences, which poses a challenge to teacher training. In a study conducted by the authors [3], participants, primarily primary and secondary school teachers from Brazil, Portugal, Cape Verde, and Angola; were offered continuous training in CT via the Teams platform within a remote context. The aim was to evaluate the impact of this training on the understanding of CT concepts and practices among these teachers. Using qualitative methods and action research dynamics, the teaching experience was designed involving the formulation of tasks as teaching hypotheses, subject to reassessments and readjustments. The teachers' contributions and involvement were significant, leading to the conception of various activity proposals and yielding results that contribute to implementing CT tasks in basic education. These tasks help develop multiple skills among children, aiding problem-solving across various areas. The participants' proposals were published and made available online to contribute to teacher training in the context of CT [4]. GeoGebra was utilized by teachers to create resources, catering to diverse aspects of mathematics education. This facilitated the adaptation or development of materials tailored to students' needs and educators' challenges in schools. The implementation of these materials in educational settings was investigated, focusing on their impact in enhancing student outcomes. Additionally, this approach enabled the provision of immediate feedback in assessment

methods. This marks a significant step toward imbuing these materials with attributes linked to AI [2].

The study conducted by the authors incorporated constructs introduced by Abar [5], highlighting the documentary work of mathematics teachers and its connection to their prior knowledge within the context of technological innovation. She posits that teachers' prior knowledge influences the selection and transformation of resources, potentially facilitating the assimilation of technological innovation. Engaged in their teaching roles, educators often face challenges in engaging with the knowledge that various theories, such as Technological Pedagogical Content Knowledge (TPCK), consider vital.

More recently, in a systematic research review, Celik et al. [12] concluded that AI provides teachers with several opportunities for improved planning, implementation, and assessment of their teaching. Teachers have varied roles in developing AI technology, including serving as models for training AI algorithms and participating in AI development. Challenges in implementing AI in teaching practice offer guidelines for advancing the field. With 428 teachers in Turkey, Celik [11] developed the Intelligent-TPACK framework, a scale measuring knowledge for instructional AI use based on the Technological, Pedagogical, and Content Knowledge (TPACK) framework, extended with ethical aspects. The findings indicated that teachers with more knowledge to interact with AI-based tools have a better understanding of AI's pedagogical contributions. Accordingly, Technological Knowledge (TK) empowers teachers to assess AI decisions more effectively. However, the effective integration of AI-based tools in education necessitates more than TK. To efficiently deploy AI in education, TK gains meaning when combined with Pedagogical Knowledge (PK), resulting in Technological Pedagogical Knowledge (TPK).

This new approach of Intelligent-TPACK encompasses consideration of threats introduced by AI systems, particularly those related to ethical aspects. Therefore, the TPACK approach remains valid, provided that ethical concerns are rigorously addressed, especially in educational or research settings in most Western countries. The challenge lies in regulating the use of AI in contexts where regulation is insufficient, particularly in projects that evade adherence to robust ethical standards or community-defined rules.

4 Final Remarks

This study aligns with the authors' empirical findings, derived from the development of other studies, exploring the role of technology, particularly AI, in mathematics education. It discusses how technology can enhance teaching and learning and how it can be integrated into the curriculum to improve student outcomes. In a school environment where teachers are encouraged to develop activities within the context of CT underlying AI.

The significance of CT and its relationship to mathematics education has been emphasized in the literature, focusing on the concept of utilizing computational tools and techniques for problem-solving and data analysis. The authors' empirical work demonstrates that CT is an essential skill for students to develop, particularly in preparation for understanding and working with AI. The integration of CT into the mathematics curriculum in many countries offers an opportunity to create activities that enhance students' knowledge not only in mathematics but also in other areas.

Given the age of AI, CT is a crucial skill for students to develop, and the guidance of a qualified teacher is essential. For teacher training, Mishra and Koehler [21] propose a framework of knowledge that includes Technological Pedagogical Content Knowledge (TPACK), emphasizing the importance of integrating technology and, by extension, CT into teaching practice. Similarly, Abar and Lavicza [7] argue that CT should be integrated into the mathematics curriculum to prepare students for the demands of the 21st-century workforce.

Mata-Pereira and Ponte [19] assert that teacher training is vital for promoting students' mathematical reasoning skills, while Abar [6] emphasize the need for ongoing professional development to assist teachers in integrating technology into their teaching practice. These arguments are supported by evidence from relevant research and literature. Therefore, the successful integration of AI in Mathematics Education necessitates a focus on teacher training and professional development. Firstly, teachers need to be equipped with the knowledge and skills to effectively integrate technology and CT into their teaching practice, even before AI integration takes place. The authors' empirical work provides evidence that this is achievable across various levels and regions, despite challenges in some countries related to weak access to infrastructure and technology, as the UNESCO report [27] points out.

The integration of technology, particularly AI, into mathematics education holds the potential to improve student outcomes and enhance teaching and learning. For example, Kovács et al. [16] argue that an ecosystem for computer-supported geometric reasoning can enhance students' problem-solving skills and foster a deeper understanding of mathematical concepts. Similarly, Abar [6] and Abar and Lavicza [7] propose that digital technologies can support student learning and engagement in mathematics.

The potential benefits of AI in Mathematics Education, such as personalized learning and improved student outcomes, were evident in the context of GeoGebra Automated Feedback tasks presented in another study. Teachers at different teaching levels could design adaptable tasks based on their Pedagogical Knowledge, particularly using practical knowledge about their students' difficulties and mistakes, whose results are published in an e-book [4]. In this sense, the GeoGebra open-source software helps mitigate potential biases in Automatic Systems.

However, some limitations stem from the restricted generalizability to other settings. While many articles and studies cite empirical evidence, some of them rely on small sample sizes or limited data, raising questions about the reliability and validity of the findings. Additionally, the reviewed studies do not comprehensively address the challenges and specific risks associated with the integration of AI into mathematics education. Although some articles touch on these issues, more research in this area is warranted.

The reviewed literature lacks extensive research on the impact of AI on the role of the teacher in mathematics education. This impact directly relates to how teachers can effectively integrate technology and CT into their teaching practice, underscoring the need for further research.

Future research should concentrate on developing and testing effective strategies for integrating technology and CT into mathematics education, especially in under-resourced schools and with marginalized student populations. Thus, more research is

necessary to explore the ethical and social implications of AI's use in mathematics education, encompassing concerns about bias, privacy, and equity.

Furthermore, future research should delve into the impact of AI on the teacher's role in mathematics education and how they can be adequately trained and supported to integrate technology and CT into their teaching practice.

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Pupils' First Experience with Moodle Learning Management System in the Classroom

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Abstract. The aim of this project is to present the experiences of primary and secondary school students when they use the Moodle learning platform as an e-learning system for the first time. We would like to evaluate these initial experiences that primary and secondary students have had when using Moodle for the first time and provide recommendations on how to avoid any difficulties that may arise for future students who will also be using this e-learning platform. As a result, over 70% of the participants in the two groups had a positive first experience using Moodle, and would like to have the rest of their courses run on the same e-learning platform.

Keywords: Moodle first-time experience · E-learning · Primary and secondary education

1 Introduction

In order to determine the perceived ease of use of our Moodle courses, we gathered students' initial experiences with Moodle and reflected on their experiences to improve the quality of course creation on the Moodle platform [1]. This will not only help us improve the quality of teaching but also facilitate their learning experience. In addition, it will allow us to develop and elaborate better procedures for introducing this platform and its activities to new users of this type.

2 Research Question

Thus, our research question is: "To what extent is a course on the Moodle learning management system challenging for students when they use this platform for the first time?".

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3 Theoretical Background

Different learning management systems are used in the e-learning area [2, 3]. One of them, which is widely used and has proven to be very easy to install and adopt across the globe, is Moodle [4]. In fact, many authors have studied the impact of such platform systems in education nowadays [5]. Studies vary from how to efficiently install it [6] to how to use it in different contexts, including in higher education [7], universities [8], or in different environments such as online gamification [9]. However, the first impression of users, especially the younger ones who will use this LMS over a long period, needs to be taken into consideration in this age of e-learning. As with any software system, Moodle does not subtract the pressure that users experience when using the software for the first time.

The introduction of a new software system in a particular field or in general life has always been a challenge for any type of user, whether a novice, an adult [10], or an expert in the field [11]. This is also true for the introduction of new technologies into the educational environment, especially as a means of teaching and learning. This is not only a challenge for teachers, but also for students [12]. According to DF Davis [13], perceived usefulness and perceived ease of use determine whether the potential user will accept a software system. He [13] describes these two views in a model called the Technology Acceptance Model (TAM). The TAM has been widely used, and several authors have applied and adapted this model [14–18]. Due to the age of the target audience we want to evaluate, we decided to adapt the TAM by designing a simple data collection process based on a unique questionnaire. We will present this questionnaire together with our methodology in the next section.

4 Research Methodology

We conducted a case study [19] in two schools. On the Moodle platform, we designed a course with similar activities for each group of the study: one group is in a primary school and the other is in a secondary school. Both groups answered the same list of questions about their respective courses. We used a 12-question questionnaire where students can only choose one plausible answer from the three options provided. We designed the questionnaire on the Moodle platform as a survey activity [20]. These questions invite them to share their first perception of the course content as well as of the Moodle platform they used. As an activity in the course, students had to take a spelling test (a pretest) and complete various exercises on spelling rules, spelling strategies, text comprehension, etc. They then write their own text and correct it using a digital spelling aid (Fig. 1).

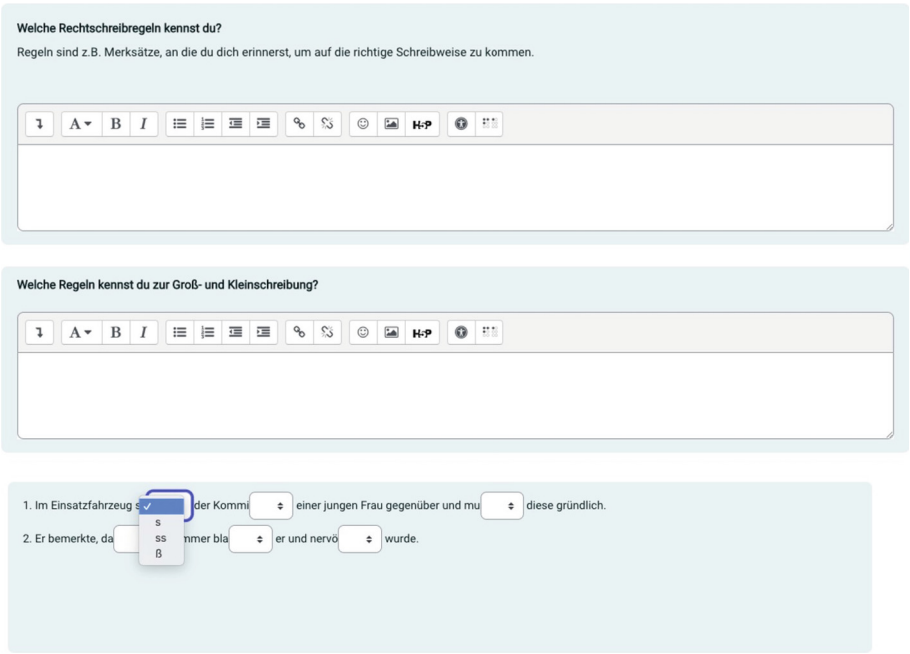


Fig.1. A spelling activity in Moodle using H5P plugin.

5 Results and Discussion

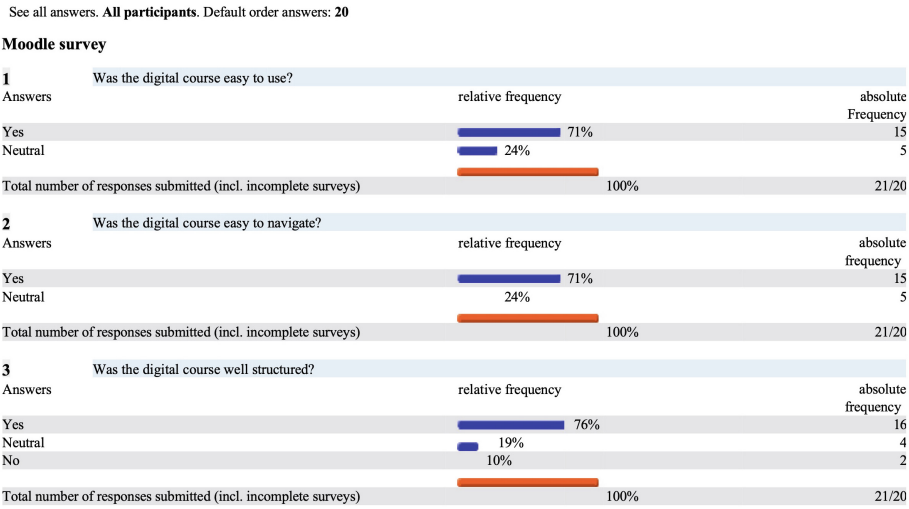
5.1 Results of the Secondary School Students

At the end of the course period, we collected the results of questionnaires from the secondary school pupils n = 20 summarized below.

Based on these responses from secondary students, we identified activities and processes that were easy and useful for them. When asked about the quality of the structure, navigation, and simplicity of the course in Moodle, over 70% responded positively. When asked if they would continue to use Moodle for their first course, over 80% responded positively. In addition, 62% of respondents agreed that they would use the Moodle platform for other courses in the future. In contrast, only 24% agreed and 62% were neutral to the fact that this digital platform was helping them to better understand the course content. Also, when asked if the new system helps them improve collaboration among themselves, more than 50% answered negatively and only 29% saw an improvement in their collaboration. Nevertheless, more than 60% had a positive experience with the tool (Figs. 2 and 3).

5.2 Results of the Primary School Pupils

Compared to the secondary student group, the primary student group (n = 20), has over 65% students who answered positively to the first question regarding the structure, navigation, and simplicity of the course in Moodle. Over 90% responded positively that


See all answers. **All participants**. Default order answers: **20**

Moodle survey

1 Was the digital course easy to use?

Answers	relative frequency	absolute Frequency
Yes	71%	15
Neutral	24%	5
Total number of responses submitted (incl. incomplete surveys)	100%	21/20

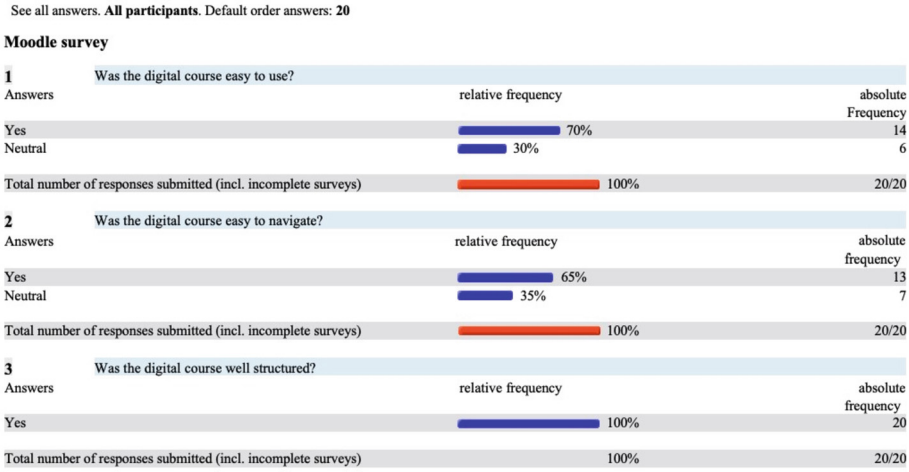
2 Was the digital course easy to navigate?

Answers	relative frequency	absolute frequency
Yes	71%	15
Neutral	24%	5
Total number of responses submitted (incl. incomplete surveys)	100%	21/20

3 Was the digital course well structured?

Answers	relative frequency	absolute frequency
Yes	76%	16
Neutral	19%	4
No	10%	2
Total number of responses submitted (incl. incomplete surveys)	100%	21/20

Fig.2. Sample of the secondary school pupils' evaluation of the Moodle course.


See all answers. **All participants**. Default order answers: **20**

Moodle survey

1 Was the digital course easy to use?

Answers	relative frequency	absolute Frequency
Yes	70%	14
Neutral	30%	6
Total number of responses submitted (incl. incomplete surveys)	100%	20/20

2 Was the digital course easy to navigate?

Answers	relative frequency	absolute frequency
Yes	65%	13
Neutral	35%	7
Total number of responses submitted (incl. incomplete surveys)	100%	20/20

3 Was the digital course well structured?

Answers	relative frequency	absolute frequency
Yes	100%	20
Total number of responses submitted (incl. incomplete surveys)	100%	20/20

Fig.3. Sample of the primary school pupils' evaluation of the Moodle course.

they would continue to use Moodle as a learning platform for their first course, and 80% would like to run additional courses on it. Only 20% saw a positive contribution of the platform to their understanding of the course, and 70% had a neutral view. When asked about the collaboration, 45% of the respondents saw an improvement from the platform, while 35% did not.

6 Conclusion

Overall, the majority of students faced various challenges, from finding the right button to perform a particular action to completing a specific task using the platform while following the explanation of the activity to be performed. Although using Moodle for the first time is quite challenging, these students requested to use this platform in other courses as well. Thus, we found that the introduction of such a system can be challenging for students, but can be overcome with proper guidance from teachers or system implementers. Therefore, good preparation or system training for teachers is key to success in implementing this type of learning management system in primary and secondary schools.

7 Limitations and Future Works

At this stage, the limitation of this study is the relatively small number of participants in the research. As a solution to this, we are currently doing other rounds of data collection in more primary and secondary schools. Based on their responses, we will identify the activities and processes that were easy and useful for them. Furthermore, we compare the didactic techniques teachers put in place to introduce this e-learning platform. We will also compare responses between schools and hopefully identify the biggest challenges for new Moodle users.

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Social Networks and Their Influence on Students of Initial, Middle and Higher Education

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Abstract. Currently, technological advances and social networks have had an impact on the transformation of the traditional methodologies of the educational system, so that more and more, all technological resources have a greater participation in the teaching process. This allows learning to be innovative and the participation of the actors involved to be creative, motivating and cooperative. This research seeks to determine the influence of social networks on students of initial, middle and higher education, as a tool to improve the teaching and learning process at these educational levels, the repercussions on the motivation to have a better school performance, the connections that can be established when using social networks when studying, in addition to the obstacles that can arise in compliance with this current scenario, which in recent years due to the pandemic has been accentuated with greater intensity. With consideration also of the risks and difficulties that may arise if they are not used properly, since, according to the educational levels of the students, timely supervision is necessary and the establishment of limits in the use for prevent unfortunate situations.

Keywords: Social networks · Initial education · Middle education · Higher education

1 Introduction

Social networks in recent years, due to technological progress and the needs of people, have had a boom in different areas of daily life, especially in education. In the case of students, they have expanded even more, since, they spend many hours in the use, making publications, interacting with others and knowing the opinions of many on various topics [1].

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Therefore, in the educational field, there has been an interest in implementing these tools and technological applications in the daily development of the system, having an impact on many activities and subjects, due to the innovative way of teaching and learning [1].

This indicates that social networks influence the lives of people, especially students, because they are linked in a social environment, and due to the various changes and needs generated in recent years, in the teaching process, the student has been having greater participation in the way he/she learns [2].

The presence of social networks in the educational system allows collaborative learning and implies participation in information exchange scenarios, which encourages cooperation, having greater knowledge in the way knowledge is processed [2]. Therefore, in this research we try to know the influence of social networks on students of initial, middle and higher education.

2 Methodology

The present research was conducted based on the systematic literature review guidelines proposed by Kitchenham (2004), in order to obtain information related to the study questions outlined for the development of the study. This normative manifest the following stages:

- Planning the review
- Conducting the review
- Analysis of results.

2.1 Planning the Review

The objective of the research is to know the social networks and their influence on students of initial, middle and higher education, with the purpose of developing the topic, the following research questions were posed:

Q1: What are social networks?
Q2: How do social networks influence early childhood education students?
Q3: How do social networks influence middle school students?
Q4: How do social networks influence higher education students?

The information was accessed through digital databases such as: Science, ACM Digital Library, Google Scholar, IEEE, Scopus, Direct Elsevier, eXplorer and Springer Link, to search for topics related to social networks and their influence on students in early, middle and higher education, modes of application, influence, research conducted on the subject. An identification of the sources found in scientific research, academic journals and technical publications, between the years 2010 and 2022, was carried out, executing as a search plan element linked to the research questions. In the search strategy, aspects related to the research questions were determined and the following criteria were followed in order to refine the inquiry (see Table 1).

Table 1. Selection criteria

Inclusion criteria	Exclusion criteria
Articles that develop the topic of the influence of social networks in early education	Information published in broad and general websites
Documents that refer to the influence of social networks on middle school students	Information from blogs
Articles that have information about the influence of social networks in higher education	Documents that do not make important contributions to the researched topic

2.2 Conducting the Review

In this phase, a selection was made of all the articles considering the inclusion and exclusion criteria, reviewing the titles of the articles, the content and the conclusions reached, with the purpose of determining whether they could contribute to the questions posed in this study.

As a result of the search, 80 papers were identified, of which 45 were selected that met the established criteria.

2.3 Analysis of Results

In order to understand what is meant by the topic of social networks, it was possible to obtain answers to Q1: What are social networks?

Social networks are various activities where people interact with other people, post images and videos, engage in conversations about public issues, read news, play games, send chat messages in real time, advertise different products and businesses, and many other elements that have to do with networks, communication and collaboration [3].

Making a definition of social networks is very challenging as they are constantly changing and updating components [4]. However, when considering a concept, it can be said that they make a description of any number of technological systems connected with community and cooperation [5].

Therefore, they employ web-based mobile technologies for the purpose of creating content that is largely interactive so that users can share, co-create, discuss, and make modifications [6]. Information is shared among users, where their interests and motivations are implicit [7–10].

Consequently, social networks allow the interaction of users to share information and create material, which are interactive so that there is greater participation of the virtual community [11, 12]. Among the most popular social networks are [13–19]:

- Content communities such as YouTube.
- Blogs such as WordPress.
- Collaborative projects such as Wikipedia.
- Social networking sites such as Facebook, Instagram, Twitter, and LinkedIn.
- Messaging applications such as Viber, Skype, and all those for academic purposes.

Social networks are used for the creation of social relationships and for educational purposes [20]. Therefore, in recent years they have been used in education at all levels [21–24]. Children, adolescents and young people use social networks for different purposes, communication, entertainment, work, sales, shopping, information exchange, news, announcements, among others [4].

Characteristics of Social Networks

Social networks have the following characteristics [1]:

- Individual connectivity: the network is formed by users, who must create a profile to register and be accepted. The affiliation is done freely by each user.
- Independence and interactivity: The networks are created based on common motivations and interests, achieving an independent integration. Interactivity is achieved because users coexist in a virtual environment, exchanging information [25].
- Freedom: Networks have the independence and responsibility for the integration and dissemination of information, as well as the creation of content, which leads to the construction of knowledge.

Social networks are relevant because they facilitate the possibility of managing information and generating content that they make available to people, and in the case of education, they allow the strengthening of learning and knowledge [1]. In addition, they have become spaces for interaction, where some show a degree of specialization, favoring the use and better use of the resource [26].

Negative Aspects and Risks of Social Networks

In the use of social networks by students at different levels, there are negative aspects and risks to which they are exposed with these new styles of communication and connection. Among some of these aspects are: depression, attention deficit hyperactivity syndrome, insomnia, decreased sleep, poor academic performance, grade repetition and school dropout [27].

There are a number of psychosocial problems linked to the use of networks, addiction to online games, which affects decision-making and feedback, due to the hours spent playing, failures in the learning process [28]. In personality, due to cyberaddiction borderline personality disorders have been detected [29, 30].

In addition, there is exposure to pornography and violence in the media, video games, social networks, internet. There is little ability to observe body language and facial expressions directly. These technological tools facilitate inappropriate behaviors such as anonymity, false identity, exhibitionism, aggressiveness, deception, among others [27].

Other dangers to which students are exposed are Grooming, where an adult person uses strategies, in order to establish links with children, adolescents and young people to achieve control and sexually abuse them [31], through friendship, deception and blackmail; Cyberbullying, has to do with the way in which the media favor violence on people, manifested as follows: publications, images, videos, memes, private information published with the purpose of embarrassing, false profiles, among others [28, 32, 33].

Among other practices that can be dangerous using the networks are sexting, which allows the sharing of sexual and personal images, with the risk that the information becomes viral without the consent of individuals, bringing consequences by being

exposed to the public [32]; cyberaddiction or addictive behavior to the Internet, characterized by losing control when using the Internet, which can affect social ties, academic performance, recreation, health and personal hygiene [30, 34, 35].

Q2: How do social networks influence early childhood education students?

Social networks have become a tool of great importance in the academic environment, since they have an impact on the way teaching and learning take place, and the student can develop a cooperative work with teachers and other classmates to achieve meaningful learning [36].

From early education, a process of familiarization with new information resources begins, with the proper supervision of teachers, so that they take into consideration the maturity stage of students, being as a guide in the proper use of technological tools [36].

In the first years of schooling, students are in a stage of knowing and learning the resources with which the teaching process is given, how to use the Internet and to what extent to alternate it with playful activities that lead to the development of all the skills and functions that should be stimulated in that initial stage [36].

Therefore, the importance of the teacher's role in these beginnings with the use of these applications and educational technological tools, having a moderating role that guarantees [37]:

Security. Since the users are minors, it is necessary to consider the control of access to the network and care in the disclosure of content. Therefore, it is necessary to have an account manager to ensure the safety of early childhood education students. If the network is a social network of the educational center, it is the management staff who is responsible for administering it, but if it is a more restricted network, more at the classroom level, the administration is assumed by the teacher.

Content Control. In order to manage the content with the corresponding delimitation, adapting it to the objective of the planning to be presented, to the needs of the students, with the appropriate and timely presentation, avoiding distractions. These contents can be from various technological resources, but with the expected educational purposes.

Improvement of Interpersonal Relationships. Education not only has to do with the intellectual development of each student, but also implies a comprehensive development, where other spheres are immersed, such as social, personal, cognitive and emotional, therefore, social networks facilitate the possibilities of also working in these other areas, while acquiring knowledge, allowing the interconnection between all students, which will be channeled through the methodological strategies applied by the teacher when using the tools.

In a study conducted to find out how social networks have an impact on early childhood education students, it was determined that students of this generation are equipped with many technologies, using social networks such as Twitter, the use of video games, video consoles and cell phones [33].

Another result obtained in the study is the ability of minors to make use of screens in different activities and exercises, performing several processes at the same time [33]. These resources allow them to communicate, play, consume and display content [38].

In the impact that social networks have on students in early education, the presence of parents and teachers plays a very important role, for the confrontation of the dangers

to which minors are exposed, the risks for which they do not have the maturity or the mechanisms to confront some content and certain inappropriate behaviors [33].

Q3: How do social networks influence high school students?

With the changes that are made in the world through technological advances, social networks allow students an opening in the management of their functions, which although it is true that it is used by education for the fulfillment of academic responsibilities, they are also used in daily life to establish links with other people [28, 39].

In the educational field, its purpose is for the teacher to generate knowledge together with the students in a constructive and cooperative manner, so that the appropriate use is achieved that leads to meaningful learning [39].

In studies conducted with high school students, to know the influence of social networks on academic performance, it was found as results: that each student has the knowledge of what social networks are, and they make use more frequently of Facebook, followed by Twitter and then Instagram [28, 39].

Although students may use social networks to research homework information, it is greater the use of the networks of their preference to interact with other people through chat and to be updated on what is happening with friends [39].

In addition, middle school students have a prolonged time of investment in social networks, which merits those parents and teachers can give appropriate guidance, because of the risks and consequences that can be generated [33].

In this evolutionary stage in which students are, there is a gap in the communication of parents with their children, there is only an endowment of technological resources without any limitation or control, which generates problems in adolescents [33].

Among the problematic situations is the so-called precocious cyberadolescence, where students have knowledge of everything, but are lost, due to the lack of teaching how to cope with the proper use of technologies. This is where the teacher and the family must play an active role to show what is appropriate, establishing parameters to prevent risks [33].

All this leads to consider the important role played by teachers and parents for the responsible use of social networks. Students should be aware of the proper way to use these tools, both inside and outside the educational institution [33].

Q4: How do social networks influence higher education students?

Social networks constitute a communication resource that has no boundaries, allowing proximity despite distance, and contact with others who have similar needs, interests and concerns [39].

Therefore, faculty in higher education are encouraged to discover or reinvent different ways to use social networks effectively, using them for content creation, sharing, participation, and collective socialization [40].

In addition, they can enable up-to-date teaching materials and educational data, which promote contact and collaboration. Many researchers argue the use of social networks to foster communication between faculty members and students, for the strengthening of the student community [41, 42].

Therefore, the use of these tools in higher education has become indispensable, since, they are young people who have risen in a generation of technology, and they need to have the training and transmission of concrete skills in the university careers they have chosen for professional preparation [43].

Social networks have provided a teaching and learning environment for both students and teachers [44], since the incorporation of these tools in the university classroom implies an effort on the part of both, so that the process is satisfactory [45], encouraging mutual help so that with the resources the solution of the needs and problems raised is sought [44].

These tools give continuity to the school activity in the classroom, but in many cases in a virtual way, allowing the expansion of continuous interaction, the incorporation of new strategies and materials for communication [45].

In a study conducted to know the influence that social networks have on higher education students, the following was found: among the most used networks are Facebook, MySpace, Twitter and Tuenti; it is a minority who use the networks for educational purposes, in addition, they do not see the networks as dangerous, they think that they do not affect their personal life [12].

This indicates that young people use social networks for academic activities but more as a means of communication, to establish links and interactions with other people, without realizing the danger of excessive and inappropriate use [12].

University students are exposed in a dangerous way, when they manifest their private life in social networks, in addition, the face-to-face relationship is shrouded in fears and difficulties to establish adequate links. Many prefer virtual interaction, but run the risk of being deceived, extorted, disappointed, which can generate low self-esteem, depression and suicide [12].

This determines that the inappropriate use of social networks can lead to unfortunate consequences. Using it in a timely and appropriate manner, understanding the benefits they have to achieve meaningful learning, training and preparation for professional life, would generate a successful and healthy outcome for students.

3 Conclusions

Social networks are immersed in the daily lives of individuals today. Technological advances with the different tools and resources they offer have made changes and adjustments in the way people function in the different areas where they develop.

And in the educational field it has had greater repercussions, in the way of teaching and learning, which has caused the respective adjustments and changes to be made in the planning of educational strategies to make the corresponding adjustments, which facilitate the training of students to make proper use of these technological resources.

Therefore, the use of social networks has had a boom at different levels of education, and both the teacher and each student have the opportunity from what corresponds to their duties and functions, to perform the planned activities and respond with the greatest effectiveness to achieve meaningful learning.

However, it is also known the risks that arise when using social networks, of which both parents and teachers must supervise and monitor the interactions that are made by these means, so that these resources are used to nurture knowledge and not to generate dangerous conditions or situations that put at risk the integrity of the most vulnerable people.

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Scholarly Communication in Distance Higher Education

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Abstract. In the distance learning modality, the communicative interaction between teacher and student, mediated by the use of information and communication technologies (ICT) and a virtual platform for the learning process and the development of academic activities, requires responsible, ethical and honest work. This interaction is based on the use of a vocabulary specific to the field of knowledge so that students, from their everyday vocabulary, do not have communicative limitations that affect the learning results; as limitations it refers to the comprehension difficulties presented by the student's vocabulary resources and as achievements it refers to the learning results. For this analysis, several elements were reviewed that contrast between the way the classroom is structured by the teacher and the way the student understands this structure and that its development is optimal; the research is mixed of qualitative and quantitative character with a sample of 131 students of fourth, fifth and seventh level of the initial education program; It was based on the study of the level of comprehension and the teacher's accompaniment. The objective was to analyze the limitations of communication and academic achievements related to cognitive and procedural aspects. The results showed that the quality of the resources contributes to the development of the competencies established in each training project because they facilitate learning through the design of the didactic resources and the student's comprehensive reading.

Keywords: key-academic activities · academic communication · distance education · reading comprehension · teacher accompaniment

1 Introduction

Professional training at the higher level is a process that involves development in the academic world. This process is manifested through the management of information in the resolution of situations that require answers and support through professional practice. Given the context of the information and knowledge society, it is necessary to constantly seek, apply and contribute to information.

Distance education has evolved over the years from a traditional approach to a more technological one. Initially, the traditional distance education process was based on pedagogical strategies in which teachers and students were physically separated, but had

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occasional face-to-face interactions. With technological advances, the virtual distance modality has emerged, allowing interaction through technological tools without space and time limitations. Within this process, the student is self-directed supported by the didactic material proposed by the teacher when there was physical interaction [1].

However, with the advent of technology in education, it was intended to improve the quality of teaching-learning through the application of new pedagogical forms. Thus, the distance mode is presented as a new way of carrying out the learning process without the physical context between students and teachers, but with the use of technological tools that allow this interaction [2].

In other words, the virtual distance modality allows that, although the factors of space and time do not coincide between student-teacher, this is a condition for the process to stop, on the contrary, there is an autonomy of learning for the process; this form of teaching is built through self-learning where the teacher is a guide but the student will have the autonomy to develop in the content in the way he/she feels more comfortable. Therefore, academic communication during the student-teacher interaction is of importance when it comes to raise the issues and guide them [3].

That is to say, the academic exercise in the distance modality is carried out in communicative interaction between teaching and learning, with not only virtual learning resources but also academic texts, classes or tutorials, learning activities, feedback, all mediated by a virtual platform.

In the distance modality, Universidad Indoamérica proposes to connect to the new era of knowledge as subjects who learn permanently, with an open and flexible mentality to the new discoveries of science and knowledge, through virtual libraries, databases, platforms, networks, among other instruments that the web offers, collaborative, autonomous and democratic learning environments will also be used and be part of a network that increases knowledge and learning.

This student model is identified with a constructivist approach by bringing together the dynamics of active learning, linking it with the theory of systems and transforming education into a living system of incorporation, processing and production of knowledge. This learning is through the Canvas virtual platform in an asynchronous way, as a didactic and communication means, as well as an educational resource in virtual tutorials, becoming a universal e-learning solution.

Translated with www.DeepL.com/Translator (free version).

This reference shows the need to determine the levels of effectiveness of academic communication between professors and students; therefore, it is important to determine what is the incidence between communication limitations and academic achievement in higher education, distance mode?

With the above, the general objective of this research is to analyze the incidence that exists between the limitations of academic communication and the achievements reached by the students of initial education, distance modality, in the comprehension of the academic vocabulary and content of classroom activities for the development of professional competences. This objective will be achieved with the application of a mixed qualitative and quantitative research methodology, where surveys for teachers and students are used, followed by a test of synonyms and antonyms with words of an academic vocabulary used in the formative projects of the university career. The sample

was selected by convenience from students of the fourth, fifth, sixth and seventh levels of the initial education career.

The students of the distance mode of the career in question, given their nature, are people with family and work responsibilities, they develop around the daily demands of such responsibilities, therefore, their vocabulary and language is the corresponding; On the other hand, the academic teaching dynamics in any field of knowledge of any university professional career, determines and builds a vocabulary and language specific to the field of knowledge; then, the academic communication between teaching and learning is developed with communicative limitations that will affect the learning outcomes and the development of professional competencies. It would assume a deficient academic process in the processing of textual information, which requires as compensation, learning activities that involve practical actions.

The research consists of the introduction, the mixed qualitative and quantitative methodology, the results obtained from the application of surveys, the tabulation and interpretation of the results, the discussion and conclusions.

2 Related Work

As background to this work, the following is a summary of research carried out in Latin America.

The studies presented in the research with the theme Evolution of distance higher education, challenges and opportunities for its management, makes a comparison between "traditional distance education and virtual distance education, where it describes that communication occurs through chats, forums, virtual messaging, e-mail, where the teacher guides learning through virtual tutorials" [4].

In the research conducted at the "Universidad Autónoma de Chiapas", they point out that each group of people adopts a specific language depending on their cultural, economic, professional, labor, etc. context [5]; therefore, the need for communication in distance higher education depends on their own characteristics and circumstances in which they develop. [5]; therefore, the need for communication in distance higher education depends on their own characteristics and circumstances in which they develop, where students must handle a particular vocabulary according to their specialty of study.

In the work, "An overview at communication in Higher Education", he expresses that communication and education are the same, that is, one cannot exist without the other, since the educational teaching process is a communicative process where the teacher and the student actively participate in the resolution of tasks and in the acquisition of new knowledge [6], therefore, the communicative skills and abilities are developed depending on the context of each training project.

Communication is a constant process in which information is received or sent depending on a social, cultural or political context; it responds to cognitive and cultural processes, it is much more than an act of emitting and receiving information. Academic communication is essential to strengthen skills for good communication practices in the classroom. With effective communication, the student learns, reinforces, constructs and reconstructs knowledge, this requires a communicative academic interaction between teacher and student [7].

It should be noted then that academic communication, which occurs between teacher and student, is the factor that mediates this learning; For this, it is relevant to define academic communication, in the work "Academic communication as argumentative construction: Reading and writing perspectives of university students", states that "an argumentative construction, insofar as the constructed knowledge is the product of a process of scientific argumentation that is taken into account in the disciplinary fields, for its legitimization and circulation" [8], where a foundation is expected, a reason that evidences the scientific result acquired through a planned and organized process of methodological strategies that the teacher proposes to take the student to a new level of learning, through an assertive, clear and precise communication in each of the subjects of study.

Academic vocabulary is used in academic communication, which are oral expressions used formally in the fields of knowledge at all levels of a career; this vocabulary refers to educational and research contents and contexts depending on the area and specialty. In the work, Propuesta metodológica para la evaluación del vocabulario académico a través de la lingüística de Corpus (Methodological proposal for the evaluation of academic vocabulary through Corpus linguistics), it states that "academic vocabulary will be understood as all that formal vocabulary, independent of the context, constituted by words of very high frequency or with a high range of occurrence throughout diverse scientific disciplines" [9].

3 Methodology

The methodology used is a mixed qualitative and quantitative research, a textual and graphic academic content of the subjects is selected for reading and measurement of content comprehension, as well as learning activities containing instruction, support reading, virtual tutoring, feedback message and product with compliance indicators. A vocabulary test of synonyms and antonyms was generated.

3.1 Participants

The population selected for the quantitative study were the students enrolled in the academic period, from April to July 2022, (A22), from fourth to seventh grade. They are one hundred and thirty-one (131) students, which corresponds to 40% of a population of three hundred and thirty (330) students under study. The selection of this group of students is made through the convenience sampling technique, in each level they have six formative projects.

It is important to express that the educational model of the UTI is socio-formative, where the teaching-learning process is developed through formative projects. These are a methodology for the development and evaluation of competencies, where new methodological elements are integrated, such as the emphasis on addressing context problems, collaborative work and knowledge management; thus, they are defined as a set of articulated actions to solve a context problem in search of a benefit or service [10]. The UTI in relation to its mission and vision, among others, promotes the development of complex thinking with different processes through the problem solving approach from a multi, inter and transdisciplinary vision.

3.2 Materials and Resources

In this research article, various materials and instruments related to the collection of information and data analysis were used. In this way, two surveys were applied, directed towards professor and students of the course studied in this document, which consisted of eighteen questions and was used to obtain information on academic communication, satisfaction with academic activities, use of technical vocabulary, fulfillment of expectations, among other relevant aspects. In the same way, a cognitive test of synonyms and antonyms was applied to the students in order to evaluate their competence in reading comprehension.

During data collection, tables and figures were generated using statistical software such as SPSS and Excel, with the aim of analyzing academic performance in relation to academic communication. Likewise, during the construction of the document, literary databases were consulted to obtain information from solid sources. Finally, these sources helped to contextualize the research findings and provide theoretical foundations.

3.3 Procedure

The sample is by convenience because students from the fourth to the seventh level of the Early Childhood Education course of the academic period A22 are selected. The research is based on the students' level of understanding in the use of the study material and the academic activities of each formative project that make up each level; and, on the part of the teacher, the accompaniment for the development of these academic activities. To measure the level of reading and comprehension of academic content, a cognitive test of synonyms and antonyms and application exercises were applied to the students. Several variables were taken in each group that are very important in the context of the diversity of students and that have a great impact due to their condition, which leads to the obligation to demand differentiated attention and accompaniment.

As primary research sources, two surveys of eighteen questions each are proposed, addressed to teachers and students with the same parameters that will serve to contrast the results; and a test to identify their reading comprehension through the use of synonyms and antonyms; For the results, tables and statistical figures will be prepared to facilitate the delivery of the results with interpretations adjusted to the data obtained, with the help of bibliographical references of several authors that will serve as support for the research (Table 1).

The student population is concentrated in all provinces of the country and the distance mode has seventeen Information Centers located in the different regions; in the Eastern region, in the provinces of Sucumbíos, Orellana, Napo, Pastaza and Morona Santiago; in the Coastal region in Esmeraldas, Manabí, Santo Domingo de los Tsáchilas, Los Ríos and El Oro; in the Highlands, Carchi, Imbabura, Azuay-Cañar, Tungurahua, Chimborazo, Pichincha and Cotopaxi; in other periods, growth is maintained in these provinces.

Table 1. Distribution of students by levels, Early Childhood Education course, distance mode.

Levels	N° Students	%
In the first place	52	16
Second	50	15
Third	37	11
Fourth	36	11
Quinta	28	8
Sixth	27	8
Seventh	40	12
Eight	60	18
Total:	**330**	**100**
Total students	330	100
Target student population from 1st to 4th grades	131	40

Note: Report 387 - AMS. Prepared by: Authors (2023)

4 Results and Discussion

The research aims to show the limitations of academic communication of the educational act at the higher level, between teacher and learning that developed with certain communication constraints and if these affect the learning outcomes and development of professional competencies, on that basis, propose guidelines for the correction and improvement of academic management of training projects, essentially considered as academic communication.

For the interpretation of the research results, it is divided into three indicators: academic communication, academic achievement and the relationship between these two indicators.

Research Indicators

Indicator 1: Academic Communication

This indicator refers to the attention provided by the professor to the students that strengthen learning and professional development, the respondents determined if the professor responds to their class messages, chat or email, in a determined time to clarify the activities established in the classroom and if the language used during tutorials is very technical, which makes it difficult to understand the subject and its support, if the proposed activities contribute to the development of the competencies established in each formative project, if the design and structure of the classroom facilitates learning; and, if the professor helps to meet the expectations of the students.

On the other hand, also the teachers, through the survey, in the same parameters, define if the students of the distance learning modality respond to their level of study and learning and to the development of competencies they expect as educators; applying the internal regulations, it determines that the teacher must plan sixteen tutorials in each

formative project, one for each week; its compliance is mandatory, they are the spaces in which the student can dispel doubts in the execution of the academic activities and, it is the teacher's function, to attend every need that the student has.

In the document Scholarly Communication: A Discipline to be Promoted, it is stated that scholarly communication:

It is the unified term to discover an emerging discipline that deals with the wide range of issues that have to do with the ways in which research results or other knowledge are communicated by authors, disseminated through different vectors, stored and processed through information systems, and preserved and analyzed by a diversity of sectors and actors [11].

It is understood then that academic communication is a factor that plays a relevant role in the transmission and reception of messages throughout the teaching-learning process, even more so in the case of distance education, where a variety of technological tools are used, so that the student appropriates the new learning and adopts this new academic vocabulary.

Indicator 2: Academic Performance

In the initial education career, sixteen synchronous tutorials are planned per formative project, each tutorial is an accompaniment in the student's learning process, which guarantees and achieves the competencies and learning results proposed in the career project; Another aspect that stands out is that in the distance learning modality, learning is autonomous, with the accompaniment and guidance of the teacher to optimize the work for the student.

In the first part of the survey applied to teachers, it refers to their participation in the classroom, if it integrates a series of elements that contribute positively to student learning and that respond to the pedagogical and curricular model, that the interaction between teachers and students responds to their needs. The classroom must be structured under the institutional policy with clearly exposed pedagogical academic content containing: subject, instruction, study material and learning outcome; and, for evaluation, the respective rubric. For this, it will also be essential that each teacher builds his or her own virtual material.

Table 2, in the second part of the survey, refers to the teacher's "general satisfaction" related to the activities he/she proposes and that contribute to their development, learning and accompaniment.

According to the results of the survey applied to teachers, 71% always communicate with students through the virtual classroom on the Canvas platform, chat or e-mail within 48 h of the request, use an academic vocabulary that limits the student's understanding always within an environment of respect and cordiality; 49% attend students in a timely manner and their activities develop competencies; and, 51% use technical vocabulary in tutorials, their classrooms have didactic resources and clear instruction. In the student survey, on the same indicators, 29% have the teacher's attention; 20% are satisfied with the activities sent; and 51% always include academic activities; 16% sometimes; and 33% never.

In recent years, as a result of the pandemic, several things have changed, including the social context in which the learning process has been developed, these are defined according to the educational model of the university based on the context in which the

Table 2. Teaching role and students

Indicators	Always	Sometimes	Never	Total
Teacher involvement: attention to students' needs, tutoring, language, etc.	1478	327	130	1.991
Overall satisfaction: activities contribute to competency development, classroom design and structure	1006	143	12	1.200
Academic activities: technical vocabulary, contains learning resources, clear instruction, vocabulary.	2584	828	71	3.551
Total	**5068**	**1298**	**213**	**9.838**
%	**52**	**13**	**2**	**100**

student develops; it has a lot of information for their training, which according to the mode of study, requires a lot of ethics and responsibility, because the student autonomously, must understand concepts, know the procedure and handling of information, it means that the student must develop a questioning, analytical, reflective attitude. It means then, that the student's training by competencies is based on the teacher's accompaniment in academic tutorials and self-learning; the teacher must tend to "learn how to learn".

Indicator 3: Relationship Between Communication and Academic Achievement

The academic performance is the result of the practice directed by the teacher and the responsibility that each student has in front of his autonomous work, that is to say, of a well defined and effectively oriented work so that the student understands the objective of fulfilling his academic activities to reach his achievements, as long as he has very well formed his study habits, an indispensable requirement in the distance modality because his work is autonomous.

In the work Hábitos de estudio y rendimiento académico. Caso de estudiantes de la licenciatura en Administración de la Unidad Académica Profesional Tejupilco, points out that: "Study habits help to know the strategies, techniques, tools and methods that students apply daily to achieve their tasks in time and form, extra-class work, exhibitions and exams" [12], It means then that, if the university provides strategies to students, they will be able to internalize and apply their learning.

According to the Institution's Evaluation Polynomial, in the academic period A22, they pass the formative projects with grades between seven and ten points; and, according to the results of the Academic Management System (SGA), the average academic performance is 8.31/10 in students with grades between 7 and 10 points, that is, in the rating scale from good to excellent, respectively; these correspond to the activities in the VLE (60%) and to the partial and final cognitive evaluation (40%); while, reviewed, the average of failed and withdrawn students is 3.31/10 points.

Article 6 of the Regulations of the Undergraduate and Graduate Student Evaluation System states that the components of the evaluation are four:

- Learning management in the environments proposed by the teacher;
- Learning management in collaborative environments (collaborative teaching);
- Learning management with autonomous activities; and,
- Learning management with practical activities.

According to the statistics of the secretariat, Table 4 shows that six (6) students withdrew and 70 failed in different training projects, since in the undergraduate the enrollment is by training project and not by level; of this group of students, the average performance is 3.31/10. Withdrawal and non-approval is for various reasons; according to information from the Secretariat, 98% of the students are women. Student Services reports that desertion is due to lack of communication with the teacher, difficulty in handling the virtual platform, limited time availability, scarce economic resources, domestic calamity, illness of the student and/or their direct family members, separation from their jobs, many of them are heads of household, among others.

The number of failed students is high, which, according to the number of students enrolled, represents between 11% and 33%, that is, between four and eight students per training project. The learning activities presented by the teacher and the work done by the students are part of the academic and communication exercise that leads to the establishment of an adequate relationship between both parties which, with the proper accompaniment, becomes the actor of learning; therefore, it is indisputable that this act of assertive communication plays an important factor in the training of future initial education professionals.

In the distance modality where autonomous work prevails, in the article Diagnóstico de necesidades y estrategias de formación docente en universidades, on the role of the tutor and advisor professor, he expresses:

The teacher, transmitter of knowledge, manager of information and educational model, must share with the student the knowledge, experiences and reflections regarding the teaching contents in an environment of dialogue, tolerance, exchange and respect that encourages participation and mutual understanding. The student goes from being only a receiver of information to being an actor in the learning process [13].

From this point of view, communication is bidirectional and essential in the learning process, the student must be stimulated being the actor of his learning, with a participative attitude, while the teacher is the tutor of that learning; therefore, the academic activities must meet the necessary requirements that facilitate the understanding of the student.

The purpose of this test is to contrast the difficulty in understanding the academic activities for the execution, if it is considered that they are autonomous and that the teacher becomes a tutor for learning; One of the aspects to highlight is the availability and use of the virtual classroom, in it each teacher inserts study material to use in each task and also material of his authorship.

To verify the hypothesis in the survey applied to both students and teachers, the two variables "**communication and academic performance"** are related, the Pearson's chi-square test is applied, a procedure with which it is determined that the value of X2 used for qualitative variables.

Hypothesis testing	
Group	Result X^2
Students	Xc2 = calculated Chi-square = 46.23
Teachers	Xc2 = calculated Chi-square = 14.64

Note: Results of hypothesis testing. Source: Survey.

The value found in the rejection zone of the null hypothesis, accepting the alternative hypothesis (Ha) that says: "Academic Communication **does affect** the academic achievements of the students of initial education, distance modality"; this is determined in the survey applied to both teachers and students, that is to say, it is verified that the hypothesis raised in the research.

5 Conclusions

The aspirations of the students are to finish their studies, obtain a professional degree and look for a job because they prefer to have a secure monthly income; the initial education student population is mainly made up of women, most of them are heads of household, single mothers who dedicate themselves more to other jobs and not to teaching, with incomes below the current minimum living wage, but their dream continues and is to have a better standard of living with a professional degree that accredits their knowledge; However, there is still distrust in their knowledge, they are afraid to ask for help from their teachers, they feel marginalized socially, professionally and economically, these are reasons to abandon their studies and they have other priorities.

In the distance mode, attendance to tutorials is not mandatory, they have the option to watch the recorded tutorials when they have time, which due to their multiple occupations, many of them do not do it, and the minor lack of knowledge to perform the tasks or difficulty to enter the virtual classroom, In view of this and based on the verification of the hypothesis in the students, communication does affect academic performance, which causes a high percentage of desertion and failure because the activities proposed by teachers are not clear and are difficult to understand. On the other hand, for the teacher, the absence of the student in tutorials and access to the classroom affects low academic performance.

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Collaborative Work and Co-teaching as 21st Century Skills for Educating from an Inclusive Perspective in Face-To-Face and Virtual Contexts

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Abstract. Educational inclusion has been promoted in Chile through international agreements and laws. Collaborative Teaching Work (CTW) is fundamental for inclusion but has faced resistance and criticism from general education teachers. Chilean policies align with international treaties, but resistance persists due to a lack of understanding of inclusion as a complex social construct.

The objective of the study was to comprehend the processes of managing collaborative work and the role of technology in educational inclusion. An ethnographic method was employed, which included interviews and ethnographic observation. The participants included educational leaders, teachers, and students from educational institutions in the Biobío and Ñuble regions.

As a result, it is found that educational leaders tend to idealize collaboration and inclusion in their institutions, but often, this is not reflected in practice. Most teachers claim to possess technological skills, but their effective use of technology is limited. Students exhibit heterogeneity in their classroom behavior, and rigidity is observed in traditional classes. There is resistance to change, a lack of teacher training, and a significant gap between the representation of school administrators and the reality in the classroom, posing significant challenges to educational inclusion. Technology is considered an important tool, but some teachers are not familiar with its use.

Keywords: Educational Inclusion · Collaborative Work · Co-Teaching · Technologies

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1 Introduction

1.1 Inclusion and Collaborative Work in Chile

International agreements and laws have promoted inclusive education in response to the diversity of learning in schools over the last decades [25]. A key strategy for achieving educational inclusion is Collaborative Teaching Work (TCD), which involves collaboration between regular education teachers and special education and/or differential education teachers [12, 22]. However, TCD has faced resistance and criticism from general education teachers [20, 22], possibly due to different perceptions of their roles within the framework of the School Integration Program (PIE) in Chile, which aims to fulfill international commitments to inclusion, focusing on students with Special Educational Needs in regular classrooms [15], without fully understanding that inclusion is a more complex social construct. Decree 83 demands the inclusion of all students [17]. Numerous documents and ministerial guidelines emphasize the importance of TCD and co-teaching between regular and differential education teachers in the development of PIE [15]. These policies are aligned with international treaties such as the Salamanca Statement and the Dakar Convention [25]. Theoretical and empirical research has highlighted the need for collaboration in educational inclusion [9, 11, 18, 23]. Furthermore, it has been emphasized that collaboration is not only crucial for students with special educational needs but for all students [11, 13].

However, resistance to TCD persists, possibly due to homogenizing educational models from the past. Research has revealed an ambiguous perception of TCD among teachers; while some see it as beneficial for equity and inclusion, others perceive it as a formality [9, 20]. Educational inclusion is considered a process of change that seeks to eliminate barriers so that all students have access to education [1, 2, 9, 11, 20, 22]. To achieve this, a collaborative culture deeply rooted in educational communities is needed [9]. Regular education teachers must recognize special education specialists as key collaborators in the learning process [8, 10, 11, 20].

Effective communication and proper management are required for TCD to overcome resistance to change [12]. However, it often focuses more on the needs of students than on changing teaching practice [11, 18]. Recent research, such as [20] in Chile, has highlighted the lack of time for TCD and differences in role perceptions among teachers. Insufficient teacher training has also been identified as a problem [22]. The research team of [22] was able to confirm the lack of time for the development of TCD and the disparity in the roles to be fulfilled by the various teachers involved in the process. It is also noted that teachers have used virtuality to overcome the lack of time. The same research finds a lack of teacher training in this regard, which aligns with findings in other studies [9, 20].

Technology in Inclusion and Collaborative Work. In addition to the virtual collaborative work that teachers had been conducting to overcome the lack of time, it should be noted that the COVID-19 pandemic has introduced virtual collaborative work in response to the lack of available time, presenting new challenges and opportunities [23, 28]. This underscores the importance of documenting and analyzing the current educational context to be prepared for future eventualities.

The above reaffirms that the essential role of technology in the educational field cannot be underestimated. In fact, [3, 16] has detailed and described twenty competencies in Information and Communication Technologies (ICT) that students in today's society should master, divided into four dimensions. It is imperative for all teachers to become familiar with these competencies, not only because [16] promotes them but also due to personal conviction and the need to adapt to Knowledge Management [5]. If teachers do not acquire skills in these tools, it becomes difficult for students to develop and use them effectively for well-planned and specific educational purposes. The claim that the new generations are "digital natives" is often heard [19]; however, most students limit themselves to browsing social networks and do not necessarily take advantage of computer tools as active and efficient technical means. Instead, they tend to use technology as an automated communication system, easily accessible with a single click [4–6].

Currently, future-oriented education is constantly evolving with the aim of meeting the demands of the 21st century and preparing students to face the challenges present in the labor and social world. This is part of what is called 21st-century skills, and among these, collaborative work is considered a fundamental competence [21]. According to [14], education should place special emphasis on the development of practical and creative skills, as well as the ability to adapt to change and solve complex problems through collaboration.

In response to this need, new educational models that promote collaboration, innovation, and the fostering of critical and creative thinking among students are being adopted [28]. In general, these innovative educational models stimulate active learning, teamwork, collaboration, communication, critical thinking, and creative problem- solving among students, skills that are essential for the 21st century [21].

2 Objetives and Method

The objective was to understand the processes of managing collaborative work in the educational inclusion process and the contribution of communication and information technologies to this management process. The research was conducted in four educational establishments in the Biobío and Ñuble regions of Chile (Table 1).

The study employed an ethnographic method, utilizing interviews and ethnographic observation [7].

PARTICIPANTS OR SUBJECTS OF STUDY:

G1: Educational leaders from Educational Organizations.
G2: Special education and regular teachers.
G4: Students from the educational establishments.

TECHNIQUES

Semi-structured ethnographic interviews and ethnographic observation: Interviews and observation are appropriate techniques in ethnographic methodologies [26]. For the purposes of this research and to meet the study's objectives, semi-structured interviews will be used as an instrument, along with a field journal [27]. A semi-structured interview is an interview that, although it has a predefined script, is not a questionnaire with

Table 1. Final Sample.

Groups	n	=
G1	**7**	
G2	**12**	
G3	**122**	**141**

Source: Own elaboration

closed-ended questions that limit interaction and qualitative depth. Similarly, the field journal aims to observe behaviors and interactions related to the subject of study, and the same interview script can be used as a guide. As it is a semi-structured script, there are no closed-ended questions, but both the interviews and ethnographic observations are organized into dimensions, which in this case are as follows: Educational inclusion, Collaborative work, Co-teaching, 21st-century skills.

Various techniques were employed to validate the qualitative approaches, following the literature's suggestion of having at least 3 [27]. Content validation involves verifying the script through content analysis [4]. Validation by supervisors or more experienced researchers [26, 27] was also carried out. Consensual validation involved obtaining the opinions of other participants directly involved in the research, avoiding reliance solely on external judges with a Ph.D. but who may not be familiar with the specific problem of the qualitative research in question.

3 Results

As part of the results of the interview analysis, educational leaders tend to idealize their role to some extent because they claim that, in general, everything works very well in their educational institutions in terms of collaborative work, inclusion, and technology use. It is necessary to clarify that in two of the educational institutions, efforts are indeed made to collaborate and advance towards effective student inclusion. The main difficulty with these leaders is that they trust that their teachers perform the functions they expect, but when classroom observations are made, traditional teaching methods are evident, including some segregating and exclusionary practices.

Most teachers explicitly claim to be technologically proficient, but in practice, the majority demonstrate technological proficiency primarily in the use of PowerPoint, without considering other tools. Furthermore, there is little connection between the use of these tools and inclusion processes. Of concern is the case of one of the schools, which, despite all the lessons learned from the Covid-19 pandemic regarding remote work due to lockdowns, does not use what they have learned in face-to-face teaching. This hinders well-planned collaborative work and does not allow for effective time management, leaving virtual collaboration as the solution to the lack of time and informal spaces.

Regarding the analysis of the ethnographic observation process, it can be said that teachers resist observation but allow it mainly due to the institution's commitment to the project. There is one school where teachers see the accompaniment and ethnographic observation as an opportunity for improvement. In the case of students, during the initial

observations, there were anomalous behaviors because observers introduced changes to the normal classroom environment. However, this changed over time, as evidenced by the students' naturalization of the teaching and learning process, viewing the observers as part of the group.

Below, a series of figures used to support the coding and analysis process will be presented. All of these were developed with the support of NVivo 14 software. Figure 1 presents an analysis of the relationships among the twenty-five most frequently recorded words throughout the observation process. In this figure, you can observe, for example, that the word "student" is associated with "observer," which may indicate a passive role of students in the classroom. The word "students" as a synonym of the former is associated with the words "seats," "distribution," and "subject," indicating rigidity in the classroom. This is reinforced when you see the multiple relationships the word "rules" has, and how "rules" is also associated with "teacher." From the analysis, it is evident that teachers value rules, especially those related to student behavior and classroom order, but not necessarily public policies. There is also very little association with the word "questions." Upon observation, it has been noticed that teachers mainly lead the class, especially regular education teachers.

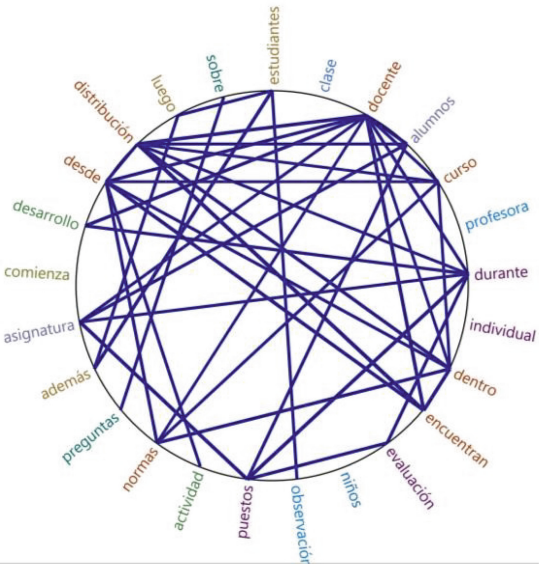

Fig. 1. Relationships between words recorded in the ethnographic observation process, developed using NVivo 14 software.

Figure 2 shows a frequency analysis of the word "docente" (teacher). In this analysis, you can appreciate the rigidity and conventionality of the classes without significant technological support, which aligns with the findings of this research. This suggests that a lack of technological integration does not contribute significantly to inclusion and

attention to diversity. Additionally, there is a direct relationship between "co- enseñanza" (co-teaching) and "profesor de asignatura" (subject teacher), confirming the common practice of conducting support co-teaching in inclusive educational contexts, as previously demonstrated.

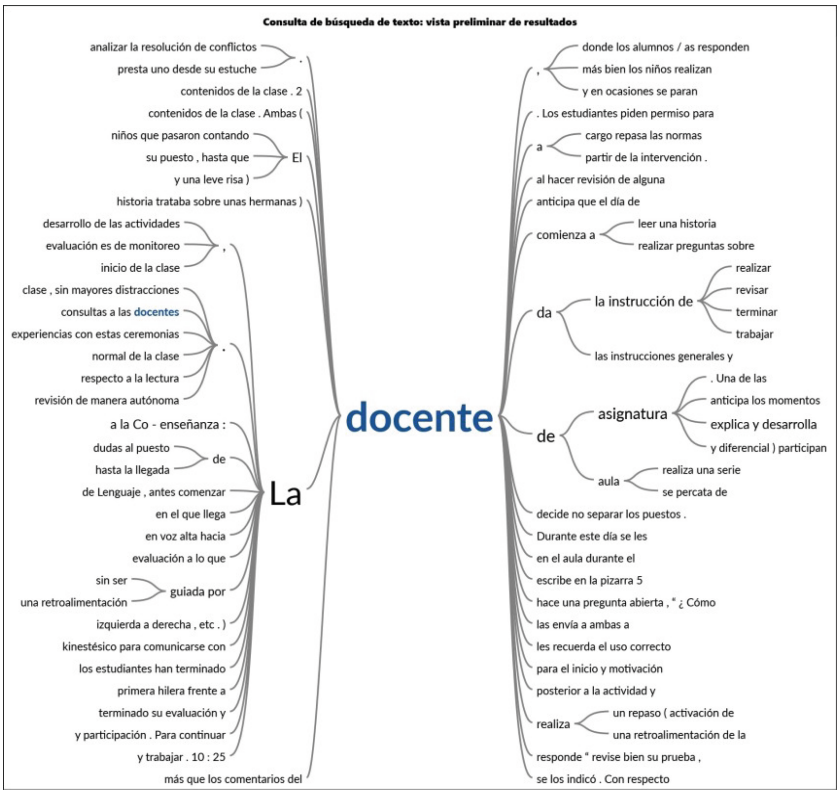

Fig. 2. Word tree for the term "docente" (teacher) in ethnographic observations, developed in NVivo 14 software.

In Fig. 3, it's evident that students exhibit quite heterogeneous behavior. Some are calm, attentive, and ask for permission, while others are not. Overall, this figure confirms the rigidity of the classes. When students appear unmotivated, the main focus is on maintaining order for a traditional classroom environment. There is even a branch in the tree where the teacher simply shouts to restore order, a behavior that has been observed frequently.

Additionally, the figure shows monitoring and segregated work with students with specific needs. While some classes attempt to address heterogeneity, they often lack adequate resources for inclusion. The primary strategy observed is segregation into groups or support co-teaching.

Figure 4 consists of two words: "enseñanza" (teaching) and "educadora" (educator), as these are the most common terms used in the educational context to refer to special

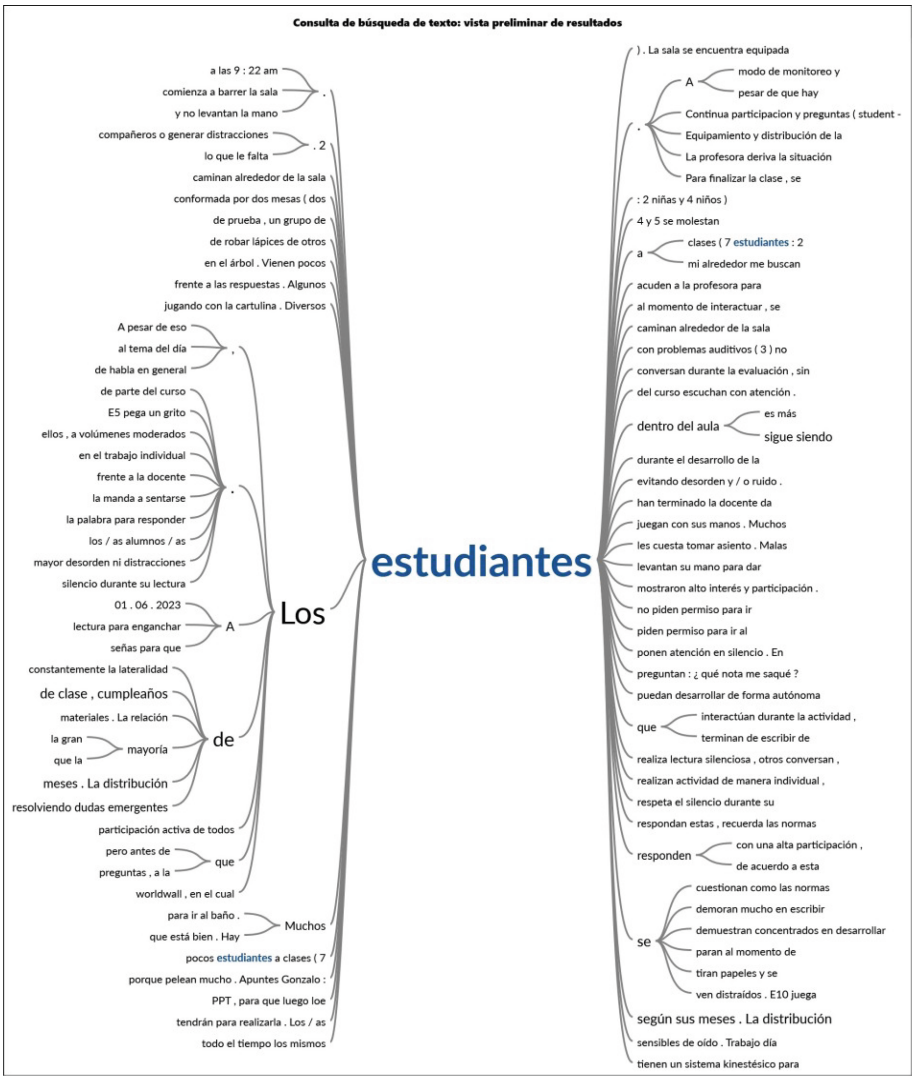

Fig. 3. Word tree for the term "estudiantes" (students) in ethnographic observations, conducted in NVivo 14 software.

education teachers. What stands out initially is the limited connection between these terms. Additionally, when it comes to co-teaching, the figure illustrates either its absence or the dominance of the subject teacher. This pattern repeats when examining the term "educadora diferencial," which is associated with support but not co-teaching.

Figure 5 is a word cloud generated from interviews with school administrators. It illustrates how the words "niños" (children), "profesores" (teachers), and "inclusión" (inclusion) are emphasized. The analysis of interviews with school directors reveals that they often idealize the inclusion process but may not be deeply involved in its

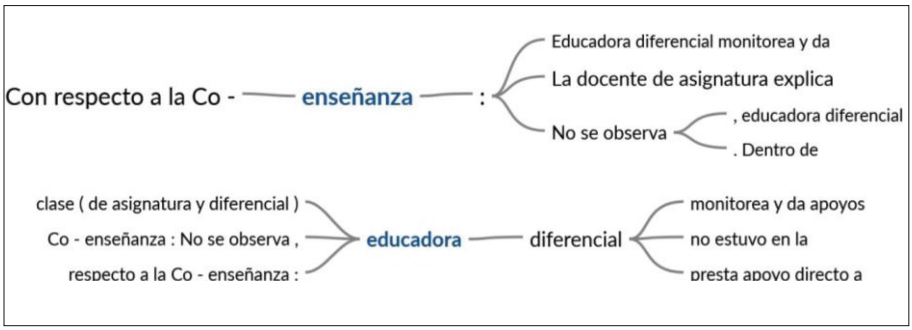

Fig. 4. Word tree for the terms "enseñanza" (teaching) and "educadora" (educator) in ethnographic observations, conducted using NVivo 14 software.

implementation. Additionally, there is a noticeable gap between their aspirations for the school and the actual practices observed in the classroom.

Fig. 5. Word tree for the term "tecnología" (technology) from teacher interviews, conducted using NVivo 14 software..

Figure 6 displays a word tree for the term "tecnología" (technology) from interviews with teachers. It highlights the limited perspective on technology, emphasizing its connection to time management and addressing time constraints. The tree also links technology with the pandemic, noting that one school discarded all the lessons learned during remote work. Teachers mentioned primarily using web 2.0 tools, such as email and WhatsApp, which they find helpful but underutilized. There's an explicit mention of fear or unfamiliarity with artificial intelligence, and technology isn't directly used for universalizing teaching and inclusion efforts.

Figure 7 presents a word tree for the term "tecnología" (technology) from interviews with school directors. It reflects their belief that technology use is extensive in their respective institutions and that teachers employ it to motivate students universally, supporting inclusion efforts. However, the issue once again lies in the gap between what directors believe is happening and what is actually occurring.

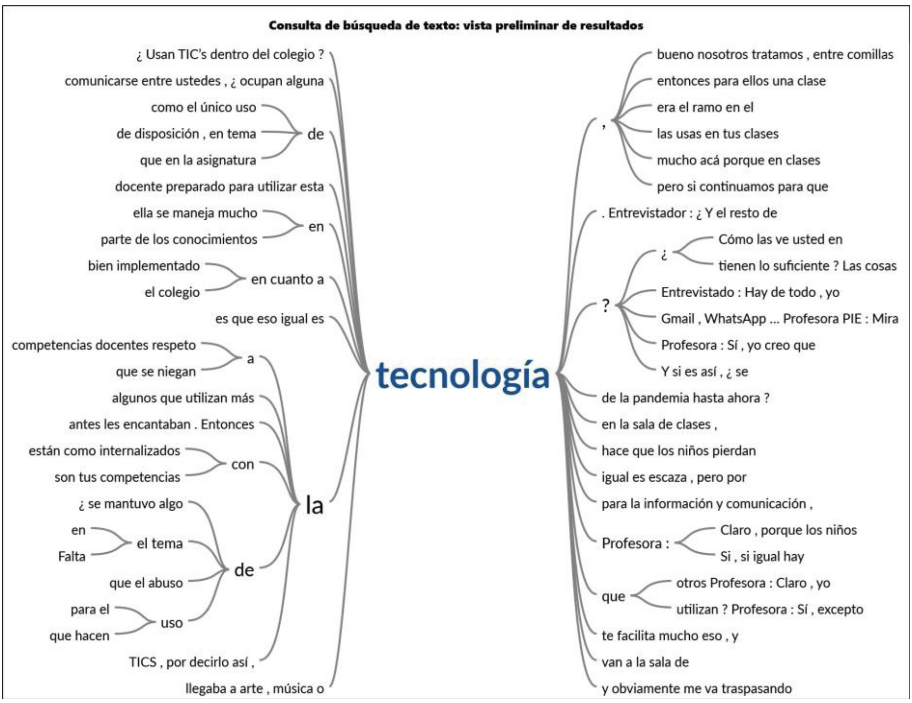

Fig. 6. Word tree for the term "tecnología" (technology) from director interviews, conducted using NVivo 14 software.

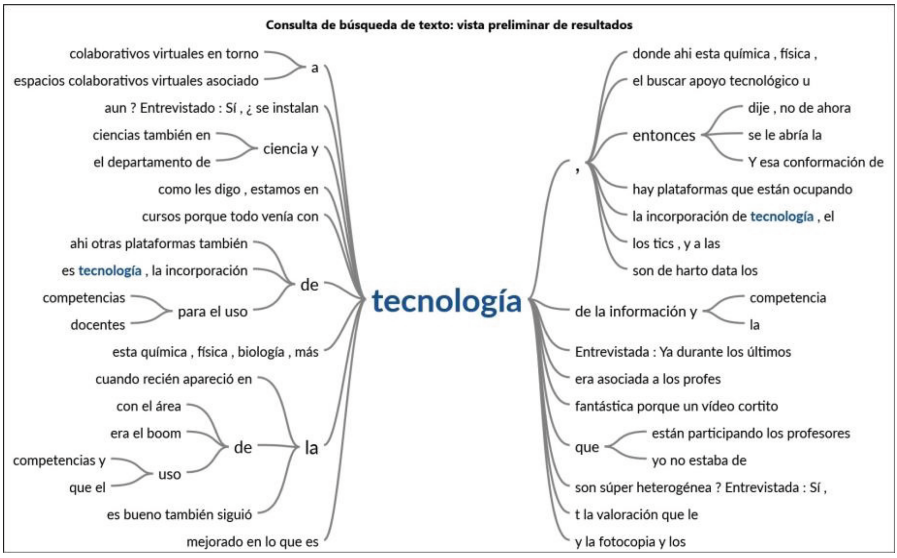

Fig. 7. Árbol de palabra tecnología aplicado a entrevistas a directivos, realizado con el software nvivo 14.

4 Discussion and Conclusion

The discussion regarding the findings of this research sheds light on several key aspects related to the implementation of Collaborative Teaching Work (TCD) and educational inclusion in the Chilean context. The authors mentioned in the theoretical framework provide a solid context for understanding these findings and their implications [1, 2, 8, 9, 11, 20, 22].

Firstly, it is evident that despite the efforts of international agreements and national laws to promote educational inclusion, TCD still faces resistance and challenges in practice. Authors like [20, 22] have pointed out that this resistance could result from differences in the perception of roles between regular and special education teachers, as well as from the lack of training and time to effectively carry out TCD.

Furthermore, the research highlights the crucial role of technology in education, especially in a world marked by the COVID-19 pandemic. The integration of technology, as mentioned in the research, can facilitate TCD and educational inclusion, considering that TCD is a 21st-century skill [21]. However, it also shows that some teachers are still not familiar with its use in this context, similar to the findings of [5]. The gap between the perception of leaders and the reality of technological implementation is a significant concern.

The lack of teacher training and resistance to change are also reflected in the findings, similar to what [11, 22] have found. Teachers, despite claiming to be comfortable with technology, often limit themselves to basic tools like PowerPoint. This underscores the need for more robust training in technology and collaborative pedagogical approaches to achieve genuine educational inclusion [3, 22].

Regarding the roles of school leaders, the results suggest that they may have an idealized view of inclusion, which does not always translate into effective actions in the classroom. This raises questions about the supervision and support provided by educational leaders in the successful implementation of TCD and inclusion, and this is a completely new finding.

Ultimately, the research emphasizes the need for a more holistic and collaborative approach to achieve educational inclusion [12]. Collaboration between regular and special education teachers, proper use of technology, and teacher training are fundamental aspects that need to be addressed to progress towards a more inclusive education in Chile, corroborating what [22, 23] have found.

In conclusion, the findings of this research highlight significant challenges in the implementation of Collaborative Teaching Work and educational inclusion in Chile. These challenges are related to the perception of roles, lack of training, resistance to change, and the gap between the perception of educational leaders and the reality in the classroom. To move towards a more inclusive education, it is essential to address these issues and promote a collaborative culture within educational communities, with a focus on technology as a tool for inclusion and proper teacher training.

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ChatGPT: Systematic Review of Potentials and Limitations in Education

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Abstract. The growth in the supply of artificial intelligence technologies in recent months has been drawing the attention of governments and public and private organizations in all economic sectors of society. In this sense, also the education sector has been showing interest in this type of emerging technologies in the market. Thus, through the present research we seek to make a systematic review of the literature on the potentialities and limitations of ChatGPT in education. The systematic review of the literature will be carried out with the support of a pre-defined set of criteria that will be essential for the serration of information on the topic addressed. The results of the research point to the existence of a set of potentialities, but also limitations of ChatGPT for education, namely for teaching-learning processes. However, like all technologies, there are always potentialities and limitations, and it is up to educational agents, especially institution directors and teachers, to adopt the most appropriate AI technologies for each learning moment. Digital and pedagogical innovation in education will always be important for student motivation, streamlining teaching-learning processes and improving the quality of education.

Keywords: Artificial intelligence · ChatGPT · Digital technologies · Education

1 Introduction

Considering the importance that technologies 4.0 have for innovation and improvement of the quality of teaching-learning processes and for the acquisition of skills by both students and teachers, it is essential to conduct research involving artificial intelligence language models in the educational context. The use of large language models in education has been identified as a potential area of interest due to the diverse range of applications they offer [1].

Studying artificial intelligence in education constitutes an indispensable contribution to the development and innovation of other educational processes. It is important to reflect that this genre of r(evolution) by itself does not serve to teach and contribute to the development of our students, but rather as one of the complements to support the teaching-learning process. It should be noted that over the years there have been different innovations in education, in the most varied dimensions, pedagogical, contextual, technological, social, among many others. Artificial intelligence is yet another

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contribution to essentially rethinking education, taking the opportunity to innovate and improve teaching processes that are sometimes already obsolete. Likewise, it is also important to understand the limitations that all technologies have, which can eventually be of different types.

Thus, this research seeks, through a systematic review of the literature, to identify the main potentialities and limitations of ChatGPT in education with a view to contributing to the discussion and reflection of the theme in the educational and scientific communities.

It is important to note that ChatGPT is a specific type of chatbot known as a "language model", which uses artificial intelligence and machine learning to generate responses based on context and previous conversation history. This model has been trained on a massive amount of data, allowing it to understand and generate human-like text with remarkable accuracy [2].

The importance of identifying both the potentialities and limitations of the ChatGPT has to do with the need to clarify the educational agents (teachers, directors of institutions, students, guardians (parents), employees and other educational actors) of the positive role that artificial intelligence has in education, but also the limitations that are also important to mention. Knowing that it is no longer possible to send artificial intelligence away from schools, institutions, organizations, in short, from our lives, it is up to us to help in the digital literacy of communities, through a balance between the two components: potentialities and limitations. In the end, after reading this article and after experimenting with this type of technology, the reader will certainly draw his conclusions.

2 Methodology

Through this research we seek to make a systematic review of the literature identifying the main potentialities and limitations of ChatGPT for education. For this, the systematic literature review is adopted as the investigative methodology to support the study. The systematic review of the literature will be carried out with the support of a pre-defined set of criteria that will be essential for the serration of information on the theme addressed, namely: (i) Time interval: 2022–2023; (ii) Keywords: chatgpt, education, potential, limitations; (iii) Documents: reference articles and doctoral theses; (iv) Search language: English and Portuguese; (v) Bibliometric databases: Scopus.

Based on the criteria previously established, the general framework of the documents found is presented (Table 1):

Three documents were excluded because they were outside the lines of the research and, in this sense, seventeen documents were considered for the purposes of this research.

The data collected from the documents that emerged from the search were categorized and treated in Microsoft Excel. Two main categories were created: potentialities and limitations. For each of these categories, all the corresponding data were associated. The following section discusses the main results, identifying the main potentialities and limitations of ChatGPT for education.

Table 1. General table of documents found.

Year	Article Title	Authors	Journal	Language
2023	The Benefits, Risks and Regulation of Using ChatGPT in Chinese Academia: A Content Analysis	Hung, J.; Chen, J	Social Sciences	English
2023	ChatGPT: An ever-increasing encroachment of artificial intelligence in online assessment in distance education	Naidu, K., Sevnarayan, K	Online Journal of Communication and Media Technologies	English
2023	How to harness the potential of ChatGPT in education?	Zhu, C.; Sun, M.; Luo, J.; Li, T.; Wang, M	Knowledge Management and E-Learning	English
2023	Chatbots in Education and Research: A Critical Examination of Ethical Implications and Solutions	Kooli, C	Sustainability - Multidisciplinary Digital Publishing Institute (MDPI)	English
2023	Can ChatGPT improve communication in hospitals?	Santandreu-Calonge, D.; Medina-Aguerrebere, P.; Hultberg, P.; Shah, M.-A	Profesional de la Informacion	English
2023	The use of ChatGPT in the digital era: Perspectives on chatbot implementation	Limna, P.; Kraiwanit, T.; Jangjarat, K.; Klayklung, P.; Chocksathaporn, P	Journal of Applied Learning and Teaching	English
2023	The role of ChatGPT in higher education: Benefits, challenges, and future research directions	Rasul, T.; Nair, S.; Kalendra, D. Robin, M.; Santini, F.; Ladeira, W. J.; Sun, M.; Day, I.; Rather, R.A.; Heathcote, L	Journal of Applied Learning and Teaching	English
2023	ChatGPT in higher education: Considerations for academic integrity and student learning	Sullivan, M.; Kelly, A.; McLaughlan, P	Journal of Applied Learning and Teaching	English
2023	ChatGPT: Bullshit spewer or the end of traditional assessments in higher education?	Rudolph, J.; Tan, S.; Tan, S	Journal of Applied Learning and Teaching	English

(*continued*)

Table 1. (*continued*)

Year	Article Title	Authors	Journal	Language
2023	ChatGPT—A double-edged sword for healthcare education? Implications for assessments of dental students	Ali, K.; Barhom, N.; Tamimi, F.; Duggal, M	European Journal of Dental Education	English
2023	Exploring the Potential of ChatGPT as an Educational Technology: An Emerging Technology Report	Glaser, N	Technology, Knowledge and Learning	English
2023	Large Language Models in Medical Education: Opportunities, Challenges, and Future Directions	Abd-Alrazaq, A.; AlSaad, R.; Alhuwail, D.; Ahmed, A.; Healy, P. M.; Latifi, S.; Aziz, S.; Damseh, R.; Alrazak, S.A.; Sheikh, J	JMIR Medical Education	English
2023	Performance of GPT-3.5 and GPT-4 on the Japanese Medical Licensing Examination: Comparison Study	Takagi, S.; Watari, T.; Erabi, A.; Sakaguchi, K	JMIR Medical Education	English
2023	Enhancing STEM learning with ChatGPT and Bing Chat as objects to think with: A case study	Vasconcelos, M.A.R.; dos Santos, R.P	Eurasia Journal of Mathematics, Science and Technology Education	English
2023	Examining the Impacts of ChatGPT on Student Motivation and Engagement	Muñoz S.A.S.; Gayoso G.G.; Huambo A.C.; Tapia R.D.C.; Incaluque J.L.; Aguila O.E.P.; Cajamarca J.C.R.; Acevedo J.E.R.; Huaranga Rivera H.V.; Arias-Gonzáles J.L	Przestrzen Spoleczna	English

(*continued*)

Table 1. (*continued*)

Year	Article Title	Authors	Journal	Language
2023	Personalized tutoring: ChatGPT as a virtual tutor for personalized learning experiences	Limo F.A.F.; Tiza D.R.H.; Roque M.M.; Herrera E.E.; Murillo J.P.M.; Huallpa J.J.; Flores V.A.A.; Castillo A.G.R.; Peña P.F.P.; Carranza C.P.M.; Gonzáles J.L.A	Przestrzen Spoleczna	English
2023	Generative Artificial Intelligence in Education, Part One: the Dynamic Frontier	Hsu, Y.-C., Ching, Y.-H	TechTrends	English
2023	Surfing the technology wave: An international perspective on enhancing teaching and learning in accounting	Al Ghatrifi, M.O.M., Al Amairi, J.S.S., Thottoli, M.M	Computers and Education: Artificial Intelligence	English
2023	Performance of ChatGPT on UK Standardized Admission Tests: Insights from the BMAT, TMUA, LNAT, and TSA Examinations	Giannos, P., Delardas, O	JMIR Medical Education	English
2023	A SWOT analysis of ChatGPT: Implications for educational practice and research	Farrokhnia, M., Banihashem, S.K., Noroozi, O., Wals, A	Innovations in Education and Teaching International	English

3 Potential and Limitations of ChatGPT in Education

Several documents were found that address some of the potentialities and limitations of ChatGPT for education, so below we discuss the main results obtained through two main categories: potentialities and limitations.

3.1 Potentialities of ChatGPT in Education

The literature analysis revealed that ChatGPT offers various potentialities for education, both for students and teachers, if used appropriately and responsibly. ChatGPT is an accessible, easy-to-use software that minimizes the time and effort spent by students and teachers in learning or academic instructions, with the potential to assist in the development of linguistic and cultural skills [3]. The time and effort reduction are also highlighted by [4], as ChatGPT has the potential to automate tasks and processes,

particularly in assessment correction and, consequently, based on the analysis of each student's responses, personalize learning experiences to meet the needs of each student. This ChatGPT feature of personalizing students' learning, as well as providing immediate feedback and support, enriches their experience, participation, and engagement in learning, which is a consensus across most analyzed documents.

Similar to other technologies, the use of ChatGPT has an impact on student motivation [4–7]. [7] even state that "… Incorporating ChatGPT into educational programs can increase students' motivation to study independently and under teacher supervision" (p. 20).

In this regard, we find relevant the study by [8] in which it is mentioned that students, when using ChatGPT as a virtual tutor, take responsibility for their learning by asking questions and making decisions, allowing them to learn autonomously, quickly, and effectively.

The potential of ChatGPT in education in general, and in specific areas such as medicine, health, STEM, accounting, or distance education, is also addressed in the analyzed literature. In this sense, ChatGPT represents a disruption in traditional approaches to teaching and evaluating distance education, in addition to assisting in the creation of different types of content and preparing students for exams [4]. In the field of medicine and health, the use of ChatGPT can enable more interactive, dynamic, and collaborative learning by applying theoretical knowledge to real-world situations, such as practicing diagnostic skills or treatment plans for virtual patients, clinical communication skills with virtual patients, and discussion with colleagues and experts [9, 10]. In the study conducted by [11], the "ChatGPT's capacity to transform STEM education by fostering critical thinking, problem-solving, and engagement in inclusive and accessible learning environments is highlighted" (p. 2). This study also emphasizes its potential in promoting creativity, collaboration, exploration, critical thinking, problem-solving, and a deeper understanding of complex concepts. Regarding the teaching and learning of accounting courses, ChatGPT can be a valuable interactive tool to help students quickly understand complex accounting concepts compared to traditional educational resources such as textbooks and manuals [12].

Furthermore, the literature refers to the importance of ChatGPT in supporting teachers, both in reducing time and workload, and in creating lesson plans, relevant teaching materials, more challenging and meaningful learning experiences for students, and innovative assessment activities that promote creativity, critical thinking, and cooperative learning [5, 13]. Therefore, teachers have more time to focus on higher-order tasks such as additional and personalized support for students or academic research [6].

Ethical and academic integrity implications are similarly discussed. Teachers should promote ethical awareness in students and provide guidelines on how to verify and critically evaluate the information generated by ChatGPT [3, 14–16].

In summary, we highlight the potential of ChatGPT in education, mentioning the work of [17] who propose a set of strategies through the use of ChatGPT as: a virtual tutor to answer students' questions; an assistant for creating learning materials; specialized support for complex tasks; a virtual learning companion; a tool for reflective learning; a stimulus for critical thinking (p. 149).

3.2 Limitations of ChatGPT in Education

The main limitations of ChatGPT in education as mentioned in the literature are related to the quality, accuracy, and timeliness of information [4, 10]. Furthermore, "The main limitation observed for ChatGPT performance on these items was that is only able to answer text-based questions and did not allow processing of questions based on images" (p. 3) [9].

The literature highlights that ChatGPT can potentially facilitate plagiarism, fraud, and academic dishonesty among students, particularly in assessment practices [13, 16–18]. Therefore, "At present, a very important limitation of ChatGPT is that it does not provide sources and quotations. Whilst it is able to provide book recommendations and provide reasons for its recommendations, it does not provide in-text referencing and a reference list in its responses. This is a major shortcoming in writing academic assignments (that usually require a certain number of references)" (p. 355) [19].

In terms of assessment, ChatGPT may not be able to replicate and adapt effective assessment strategies [13].

Furthermore, aspects such as data protection [16], privacy and security [12], or even discrimination [5] are among the mentioned concerns that hinder or limit the use of ChatGPT in education. Additionally, the potential misuse of ChatGPT for malicious purposes, such as generating fake and biased news and propaganda, is also a concern [16].

Another shared concern among some authors [7, 9, 13, 17, 18] is related to equity, accessibility, and digital inequality, which can be exacerbated if students do not have access to these digital technologies and need to pay for a subscription, further deepening exclusion and social inequalities.

However, despite the aforementioned limitations and concerns about ChatGPT, it appears that the significant limitation lies in social, interpersonal, relational, and emotional skills and competencies, which are uniquely human. Therefore, the lack of human interaction, empathy, the ability to understand context and nuances in the same way humans do, such as cultural, ethnic, gender, and identity differences [4, 5, 10, 14, 16, 18]. In this regard, "By taking over routine tasks, ChatGPT enables teachers to focus more on cultivating students' critical thinking, creativity, and interpersonal skills—areas where AI still cannot compete" (p. 17) [18]. And [19] add "AI is less competent with content that requires higher-order thinking (critical, analytical thinking)" (p. 349).

4 Conclusions

The research allowed to contribute to the discussion of artificial intelligence in education, especially its role in the motivation of students and the innovation and dynamization of teaching-learning processes. Two main categories were created, by which the main results obtained during this research were grouped.

The main features of ChatGPT are constant and immediate support and feedback; specialized support for complex tasks; increased motivation, participation, and involvement in learning; interactive and meaningful learning; stimulating creativity, critical and reflective thinking; helping teachers to create materials, activities and learning assessments.

The principal limitations essentially indicate concerns related to academic integrity, privacy, and security; the possible lack of quality, accuracy and timeliness of information; the absence of specific human skills, such as interpersonal and emotional skills, sensitivity and discernment; the possible increase in digital and social inequalities.

Although ChatGPT has potential as an additional educational tool, its potential and limitations must be carefully considered in the context of specific teaching levels, subject areas, and assessment formats. We stress the importance of integrating ChatGPT into a comprehensive learning strategy, without ignoring its limitations. To this end, educators and researchers should continue to explore ChatGPT to enhance its educational use, enriching teaching, and learning. But also address the ethical concerns and risks associated with its misuse, establishing preventive measures and guidelines. In conclusion, we believe that ChatGPT could have enormous potential to help transform education if it is used ethically and responsibly.

This research is in fact an important study that contributes to the technical-pedagogical literacy of all educational agents, but especially teachers, as they are the ones who define which technologies to integrate into the teaching-learning process. Giving teachers access to a systematic literature review that summarizes both the potential and the limitations of AI in Education, in particular ChatGPT, contributes to faster decision-making, with all the data available.

It should also be noted that AI is experiencing exponential growth in all economic sectors of society and education is obviously one of the most affected by this AI boom. However, it is important to note that the integration of AI tools obviously depends on the context in which the teaching-learning process takes place, but also on the pedagogy adopted to boost the educational process.

Finally, it is important to mention that this research contributed to the broad discussion on the subject both in the educational communities and in the scientific community, hoping that it will contribute equally to the literature in the area and to the reflections of educational agents [20].

5 Limitations and Future Research

There are some limitations underlying this research. Initially, this research is solely based on Scopus and does not consider other significant academic databases such as Web of Science. Furthermore, the review is not comprehensive or representative of all research evaluation criteria in education, as it was limited to these keywords. Finally, the authors only examined more recent data via Scopus, focusing on data from 2022 to 2023 (August), to analyze the potentialities and limitations of ChatGPT in education.

Despite these limitations, our study provides valuable insights into the potentialities and limitations of ChatGPT in education.

Future work could consider these limitations and involve using other databases like the Web of Science e additional keywords. Another important focus that could be relevant is exploring the impact of ChatGPT or other AI technologies on teaching and learning in higher education would be valuable.

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Impact of E-Learning on Literacy Learning in the New Academic Normality

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Abstract. The research of this topic is important at national and international level because it analyzes what happened on March 11, 2020, date on which the World Health Organization declares the coronavirus pandemic; in the same declaration several actions such as forced confinement, social distancing and paralysis of face-to-face activities around the world are provoked. Education was not the exception, challenges were created to comply with academic tasks of all kinds; unfortunately, it was expected that certain areas of education would face great difficulties such as the process of reading and writing. This research visualizes the process of teaching and learning of literacy in virtual education during the new academic normality, diagnoses the process of training and acquisition of knowledge virtually during the pandemic, determines the predominant difficulties of literacy in post-pandemic and analyzes the impact of virtual education during the pandemic. From the qualitative method, it is possible to assess the impact of educational learning on students at the national level through three phases: Phase 1 establishes a diagnosis of the virtual teaching of literacy, Phase 2 determines the predominant difficulties of literacy in post pandemic, and finally, Phase 3 analyzes the impact of virtual teaching during the pandemic. With respect to the above, the data collection instruments applied to 120 basic education students of a public institution in Ecuador were validated through external peer review. The results obtained are the diagnosis of virtual teaching during the COVID 19 pandemic, predominant difficulties of reading and writing in post pandemic, analysis of the reeducation of reading and writing in post pandemic. Finally, the results were socialized with the teachers in order to support the educational processes in literacy.

Keywords: Learning · teaching · data collection · reading and writing

1 Introduction

The integration of Information and Communication Technologies (ICT) has made significant contributions to the education system by enhancing digitalization and facilitating access to information. As evidenced by the efforts of the Ministry of Education through

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courses, seminars, and conferences, this advancement, however, poses considerable challenges, particularly the imperative need for educator training and the improvement of digital competence, especially in Web 2.0 tools. Without the provision of adequate training and continuous professional development, effective improvement in the quality of education remains elusive [1].

The swift and transformative changes brought about by the COVID-19 pandemic have had a significant impact on the field of education, where many educational institutions found themselves without digital platforms. Educators had to be prepared to use digital teaching strategies, and students faced obstacles such as limited internet access and a lack of technological equipment, hindering their learning experiences. In this context, virtual education played a pivotal role in influencing literacy learning during the pandemic. The Colombian education system, which had remained stagnant for several years, underwent a remarkable transformation marked by the adoption of innovative approaches and the promotion of greater student autonomy in the learning process. This transformation was accompanied by an increase in parental involvement in education, significantly benefiting students. However, it is worth noting that the pandemic exacerbated pre existing inequalities among households, affecting students' academic progress. To address these challenges, the education sector must ensure equitable access to essential resources that facilitate optimal learning [2].

The pandemic necessitated a reconfiguration of the educational environment, strengthening the relationships between educators and families. This restructuring improved collaboration in various educational sectors, encouraging families to participate more actively in their children's educational journey. The integration of technology in education had a positive impact on the learning process and contributed to enhancing students' mental well-being. It is noteworthy that virtual reality emerged as an innovative tool with the potential to enhance education and mental health, effectively shaping the future of education and pedagogical concepts [3].

Despite the multifaceted challenges posed by virtual education, it also presented opportunities to develop digital skills and discover effective methods for leveraging digital resources [4]. This article stands out for emphasizing the positive impact of ICT on education and literacy, especially in the context of the COVID-19 pandemic. It underscores the crucial importance of promoting digital competence among educators and provides a comprehensive perspective on how technology can enhance education in response to disruptive events such as the pandemic.

2 Methodology

The development of research requires a series of procedures to guarantee the understanding of the investigated reality and in this process to obtain the necessary information capable of characterizing the context in which the investigated object will develop, the specificities of the ongoing events and the specificities of the subject that is part of it. A method route is "A path of steps, techniques and procedures that a researcher employs to pose and solve a problem." [5]. In this sense, the current scenario offers and demonstrates a set of methods, techniques and procedures that, depending on the paradigm, subject and position of the researcher, will be necessary to record and process information

related to the impact of virtual teaching on literacy learning in the new academic norm. The construction of scientific knowledge requires a normal scheme that researchers and society accept and accept to frame, see, read, explain or view a phenomenon, and must clarify certain positions of researchers, define what should be studied, what questions should be answered, how to ask and what rules should be followed to explain the answers obtained", that is the paradigm [6]. Thus, under the epistemological view, it should be noted that this study is in a positivist paradigm based on descriptive quantitative methods and a parallel triangulation design [7], the justification for this approach lies in the fact that the research focuses on numerical data, that is, information that can be expressed quantitatively, such as percentages, precise figures, ratios, etc. These quantitative data allow for statistical and mathematical analyses that facilitate the drawing of conclusions. The proposed strategy is formulated using a deductive approach that emphasizes the validation of theories formed by empirical and positivist philosophies.The study is also descriptive in the sense that it attempts to collect quantitative information that can be used in statistical analysis of population samples, a popular marketing research tool that collects and describes the nature of populations as they develop. Therefore, the purpose of descriptive research is to describe the characteristics of the study population. For example, it may be a description of a person's behavior without explaining its causes. In this order of ideas, this study is defined as a second level study with a mixed approach, where the participatory action research (PAR) technique is used, this instrument is a method of social interventional participation, where the objective is that the participants of the sample are active in the procedure and the choices that are made for the solution of a given problem, being this action selected by the people [8].

2.1 Participants

In our case, human behavior will be reflected in the conceptions of the key informants who are the sixth and seventh level students of Basic Education of the "Universidad Indoamericana", located in the parish of La Matrizia, city of Ambato, Province of Tungurahua, Ecuador. Currently, there are 56 sixth level students and 66 seventh level students. To develop the research, a population of 122 students was considered.

2.2 Instruments

Within this context, we find that descriptive research corresponds to a secondary level of research. Its main objective is to collect information and data mainly on the different characteristics of the actors and institutions that make up the social processes. According to the author, this type of research employs such information to test the hypothesis or answer questions related to the current situation of the subjects of the study [9]. In this research, the participatory action research (PAR) technique was applied as the main tool. This tool is carried out under an approach in which members of a community actively participate in the collection and analysis of information, as well as in taking actions to address identified problems and promote social change.

2.3 Procedure

This study aims to address the research question: "How can virtual teaching strategies be designed for literacy learning in the new academic normality of sixth and seventh-level students at a private university?" It utilizes participatory action research as a technique to promote social change and improve the quality of life for individuals and their communities. The study consists of three phases and employs a qualitative approach to analyze the reading and writing teaching and learning process in virtual education within the context of the new academic normality.

In Phase 1, a diagnostic study of virtual literacy education during the COVID-19 pandemic was conducted. Data were collected through surveys administered to 120 elementary school teachers in a public institution in Ecuador. In Phase 2, the study identified the primary literacy challenges in the post-pandemic period by analyzing data from Phase 1. Specific difficulties faced by students in learning to read and write were determined using qualitative methods. In Phase 3, an analysis of the impact of online education during the pandemic on literacy skill development was carried out. Data from the previous phases were thoroughly examined to identify patterns, trends, and significant outcomes, providing insights into how online education affected students' literacy learning. It's worth noting that the study ensured data reliability and appropriateness through external peer review, as depicted in Fig. 1.

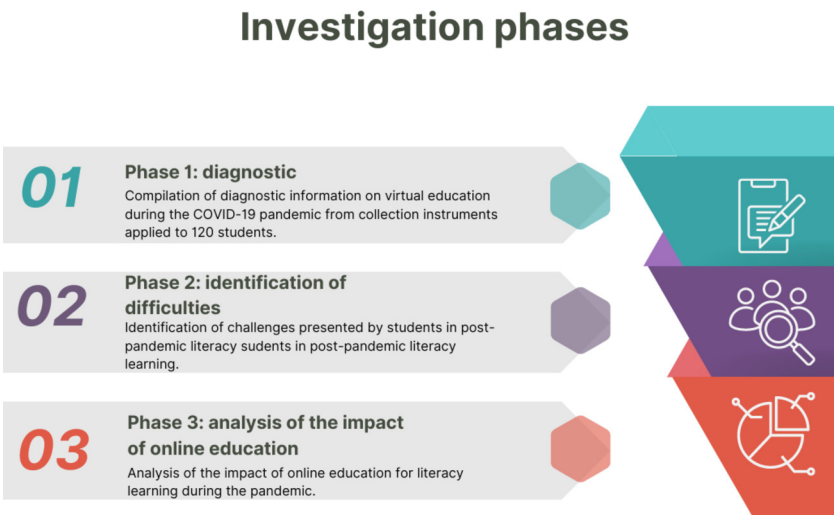

Fig. 1. Phases of the investigation

Consequently, participatory action research (PAR) served as the primary technique, aiming to design virtual education methods to enhance the acquisition of literacy knowledge in the new academic normality. Research conducted under this technique has been defined as a procedure in which team members gather and assess information, taking action on their challenges with the goal of finding solutions and fostering both political and social changes [10].

It should be noted that, in the development of this study, surveys were administered to participants using a rating scale ranging from 1 to 5. On this scale, a value of 1 represents "completely agree," and a value of 5 represents "completely disagree." The primary purpose of these surveys was to gather information about teachers' perceptions in the post-pandemic context and education. Through these surveys, a deeper understanding of teachers' opinions and assessments regarding virtual teaching and the difficulties they faced during this period of transitioning to the new academic normality was sought.

3 Results and Discussion

The measurement instruments were adapted by means of a form with 17 closed questions, taking into account the indicators as shown in Table 1. 43% of the answers obtained by the key informants corresponded to the option in agreement, followed by the option in complete agreement with 29%. The results obtained reflect favorably. The results of: You believe that the interest and motivation for learning literacy was affected with virtual education with 46%.

In the survey conducted, it was found from the perspective of teachers that the institutions were not prepared with virtual platforms for online education, which led to difficulties in the teaching of literacy in virtual meetings with students. However, it was considered that virtual teaching meets the objectives of the teaching-learning process and communication within the course, as mentioned by [11]; digital tools favor the links between people and concepts, which leads to a more meaningful knowledge in the educational process, where it is emphasized that the application of digitalized playful strategies allows socialization spaces and promotes group work within the classroom; thus allowing the student to stop being a spectator and become an active participant in their learning.

The findings of this study provide a nuanced analysis of the challenges and opportunities in the context of virtual education, particularly concerning the development of students' reading skills during the new academic normality. One notable observation is the satisfactory achievement of the program objectives outlined by the Ministry of Education by the teachers in the educational institution. However, despite these accomplishments, there remains a significant and pertinent concern related to the reading skills of the students.

The research identifies three main factors contributing to these ongoing challenges. Firstly, the existence of pre-existing learning gaps among students is a significant consideration. Some students may have faced difficulties in reading even before the pandemic. Although commendable efforts have been made to improve the teaching process, these learning gaps may still persist. This suggests that comprehensive long-term strategies may be necessary to address these gaps. Secondly, the adaptation to the new academic normality has introduced unique dynamics in the educational landscape. The study highlights how this transition may have negatively affected the motivation and commitment of some students to their studies, potentially leading to reduced interest in reading. This finding underscores the importance of considering the psychological and emotional aspects of student engagement in the virtual learning environment. Thirdly, the research draws attention to the individual needs of students in virtual education. It is essential

Table 1. Final results table

Survey to students of the faculty of education science							
	Items	Totally agree	Agreed	Undecided	Disagree	Strongly disagree	Remarks
1	Do you think that the interest and motivation for literacy learning was affected by virtual education?	46	29	3	12	10	Most of the respondents consider that the interest and motivation for learning literacy was affected with virtual education
2	Do you consider that the teaching meets the objectives of the teaching-learning process?	24	37	20	16	3	There is great uncertainty in the teaching position as to whether or not the teaching and learning processes are being complied with at present
3	Do you consider that the teacher-student relationship was affected during the pandemic?	36	40	6	12	6	76% of respondents share that the student-student relationship was affected throughout the pandemic
4	Do you think that in e-learning: chats, forums, etc. are a good way to communicate with students?	31	34	10	14	11	It is evident that activities such as chats and forums were of great help for teacher-student communication

(*continued*)

Table 1. (*continued*)

Survey to students of the faculty of education science							
	Items	Totally agree	Agreed	Undecided	Disagree	Strongly disagree	Remarks
5	Did virtual tutoring allow a real academic support in the process of teaching and learning literacy to the student?	32	41	13	10	4	The majority of the surveyed population considers that tutoring was key in the teaching and learning process in literacy
6	Did the virtual education comply with the academic didactic processes proposed for reading and writing?	27	34	19	17	3	There is considerable controversy among teachers as to whether or not the challenges that education demands with respect to literacy in times of pandemic have been met
7	Was the time used by the teacher for the student's e-learning adequate?	28	37	8	22	5	Although most of the teachers consider that the time allocated to learning was adequate, a large number of them consider that it would have been pertinent to expand or reinforce this aspect

(*continued*)

Table 1. (*continued*)

Survey to students of the faculty of education science							
	Items	Totally agree	Agreed	Undecided	Disagree	Strongly disagree	Remarks
8	As a teacher, do you consider that you were trained in the elaboration and management of digital resources to develop virtual literacy classes?	26	40	11	17	6	Most of the teachers consider that they had the necessary preparation and knowledge to develop their classes well during the virtualization process
9	Did the planning done for the face-to-face activities serve or were they useful for the change to virtual education?	28	51	7	9	5	Very few teachers had to completely restructure their lesson plans, most of them were able to make useful use of these resources and adapt them to the virtual world with some methods
10	Does it use digital resources in accordance with the contents of the study plans and programs indicated by the MEN?	37	50	7	5	1	87% of teachers comply with the criteria and suggestions given by the MEN for quality virtual education

(*continued*)

Table 1. (*continued*)

Survey to students of the faculty of education science							
	Items	Totally agree	Agreed	Undecided	Disagree	Strongly disagree	Remarks
11	Do you consider that educational institutions were prepared with virtual platforms for online education?	15	27	3	30	25	Most teachers believe that EIs did not have what was needed (in terms of resources, preparation and support) to deal with virtuality during the pandemic
12	Were there any difficulties in the teaching and learning of literacy in the virtual meetings with students?	25	55	6	9	5	Very few teachers consider that the teaching and learning of literacy was optimal during virtuality. For the rest, it was a challenge that could not be met satisfactorily
13	Do the resources you use in literacy allow students to promote inquiry and creativity?	31	59	8	2	0	Most teachers are confident about the resources they use for literacy development and how they are a quality support for their students

(*continued*)

Table 1. (*continued*)

Survey to students of the faculty of education science							
	Items	Totally agree	Agreed	Undecided	Disagree	Strongly disagree	Remarks
14	For the development of the tasks, the student performs them without the accompaniment of another person?	19	40	13	24	4	There is great controversy as to whether or not students can count on the support of third parties for the development of their academic activities and also as to whether or not this support is pertinent
15	Do you consider that the student's learning level in reading and writing has reached the achievement results set by the teacher?	25	52	11	10	2	77% of teachers share that their students have reached the goals and/or achievements they had proposed for the present with respect to reading and writing
16	Do you consider that at present students' learning in reading and writing presents many difficulties?	31	54	6	5	4	For the majority of the educational population, good reading and writing processes still represent a great challenge to be met

(*continued*)

Table 1. (*continued*)

Survey to students of the faculty of education science							
	Items	Totally agree	Agreed	Undecided	Disagree	Strongly disagree	Remarks
17	Do you visualize an improvement in the process of teaching and learning literacy in the new academic normal?	37	52	7	3	1	Most of the teachers believe that since the normalization of academic activities, the students' reading and writing process has shown a significant and positive change and represents an educational improvement
Grand totals		29	43	9	13	6	

Source: Research project applied in the Faculty of Education Sciences

to recognize that, while students are provided autonomy in their learning tasks, not all students are equally prepared or comfortable with virtual education. The study raises the question of how to effectively address these diverse needs and adapt teaching methods to accommodate individual differences. This requires personalized and flexible teaching and support approaches, emphasizing the importance of student-centered strategies.

4 Conclusions

This research emphasizes the importance of utilizing measurement tools in educational project planning to ensure alignment with the specific needs of the target population. The research employed a measurement tool to assess the digital competence of the study population, identifying significant shortcomings, particularly in the creation of digital content.

To evaluate the impact of virtual teaching on literacy learning in the new academic normal, a data collection tool design model was employed. The results indicated that while some aspects, such as the use of resources to promote inquiry and creativity, received favorable responses (59% agreement), challenges were observed in other areas. Notably, student interest and motivation for learning literacy were adversely affected by virtual education (46% totally agree), and difficulties in the teaching and learning of literacy during virtual meetings were identified (55% agreement). However, there was a perception of improvement in the teaching and learning of reading and writing in the new academic normality (52% agreement).

The research findings suggest that strategies are needed to enhance student engagement and motivation within the virtual education framework. Additionally, addressing digital competence, especially in content creation, is crucial to harness the full potential of technological tools in education. The study acknowledges some limitations, such as its focus on a specific group of sixth and seventh-grade students in a particular geographic location. Future research should concentrate on developing concrete strategies to enhance teacher preparedness and address the identified challenges. An interdisciplinary approach involving experts in pedagogy, educational technology, and educational psychology is recommended for a more comprehensive analysis of literacy in the new educational normality.

Finally, this research indicates the potential for improvement in the teaching and learning process of literacy in the new academic normality. By designing effective strategies and considering the identified needs and challenges, virtual education can become a powerful tool for enhancing students' skills and learning processes.

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Basic Education Professionals' Perceptions of Digital Literacy

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Abstract. It is recognized that it is important to develop activities that involve children in the use of different digital resources. However, this involvement must be gone with, mediated, and supervised by a responsible and knowledgeable adult, thus making digital resources helpful and beneficial for the progress of children's different skills. The research we have carried out has focused, among other things, on the following goal: To understand the beliefs of kindergarten teachers and 1st cycle elementary school (1st CEB) teachers about the strengths and weaknesses of their digital literacy, to assess the different stages or levels of digital skills development. Data collection, using a questionnaire survey, was carried out in a school grouping in a city in the north-east of mainland Portugal. Considering the results obtained, it should be noted that some steps are being taken to implement digital literacy in educational contexts. However, we believe that some aspects can be worked on and developed to promote the use of digital technologies, to prepare children for a more digital, innovative, and creative age, without neglecting their safety and preferences. There are sometimes difficulties experienced by professionals that cause them to put off using digital technologies in their educational practices, either because of the age group they work with or because they are unwilling to invest more in their training.

Keywords: Digital Literacy · Professionals' Perceptions · Digital Resources

1 Introduction

We are facing the transformation of industrial society into a more technological society, i.e., a society that is informed, communicative, reflective, participative, and more digitally savvy. Fernandes [1] states that these transformations have brought with them "new political, economic and cultural scenarios", thus challenging the education system (p.35). In this vein, schools must be available, flexible, and linked to digital technologies, adjusting to significant advances in information and communication, since technologies are part of children's daily lives, thus recognizing the potential of digital resources in their teaching-learning process [1].

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ICT promotes innovation in teaching, creating a break with existing traditional practices that promote monotony [2]. In this way, "teachers move from being mere teachers of specific subjects to mediators and feedback providers for their students' learning" [3, p. 1095]. Children benefit in the sense that they have more inclusive and diverse teaching and learning practices, encouraging them throughout the teaching process [2]. Children prefer "interactivity, speed, color, movement, [rather than] having a monotone adult transmitting information", allowing them to feel more motivated to develop their learning [4, p. 11)]. It is therefore necessary for education professionals to learn, develop, and gather a set of digital skills and to be familiar with various digital learning strategies, in the short, medium, and long term, so that the child's success and progress in school is helpful, effective, and consistent [5].

Digital literacy has brought many advantages for training and developing digital skills, both for educators/teachers and for children. The use of digital resources influences the way children think, play, and learn, as well as developing essential skills in reading, writing, communication, and mathematical reasoning. Through these skills, children actively engage "with the digital environment, developing multiple skills, including their ability to participate, their expression and identity" [6, p. 112].

Educators/teachers must invest in their digital training to develop new skills and deepen those they have already bought. As such, the European Digital Competence Framework for Educators (DigCompEdu) makes it possible to assess and certify the digital competencies of each educator/teacher, with the main purpose of understanding and characterizing them [7]. These competencies are essential and relevant for significant changes to take place in educational practices and, at the same time, for there to be an improvement in the performance of educators/teachers in terms of the digital age, i.e., the proper use of technologies [8].

Lucas and Moreira [7] state that DigCompEdu has become "a widely accepted tool for the assessment and certification of Digital Competence and has been used as a basis for teacher training and professional development in Europe and beyond" (p. 15). DigCompEdu proposed a progression model based on six different levels, in which "proficiency statements were provided for self-assessment" [7, p. 27]. The main aim of this progression model was to support/help educators/teachers in showing their strengths and weaknesses in terms of their digital development. The 6 levels of competence range from level A1 to level C2 and are related "to the six levels of proficiency used by the Common European Framework of Reference for Languages (CEFRL)" [7, p. 28]. DigCompEdu decided to include the six levels of the CEFRL as motivating performance descriptors, with the main functions of stimulating and encouraging education professionals to deepen their knowledge and develop their skills in the digital world [7]. The six levels of competence developed and characterized by DigCompEdu were called newcomer (A1), explorer (A2), integrator (B1), expert (B2), leader (C1), and pioneer (C2). The first two levels (A1 and A2) mean that educators/teachers recognize the potential and efficiency of digital technologies. The newcomer is aware of the importance of digital technologies in pedagogical and professional practice, but has little knowledge in this area, thus requiring greater guidance and encouragement to develop/apply their digital skills. In the case of the explorer, it should be noted that they already understand the potential of technologies in the teaching-learning process of children and can carry out

some activities involving technologies, but in a very restricted and limited way. At this level, it is essential to share practices with other colleagues to inspire and encourage educators/teachers to further explore their digital competence [7]. At the next two levels of ability (B1 and B2), education professionals can apply, extend, and reflect on their digital interventions. Both already use digital resources with some frequency in their pedagogical and professional practices, in a creative way. It should only be noted that the integrator is not yet as confident in implementing digital technologies in their practices and is looking to broaden their knowledge and learn about new digital tools, as well as strategies and methods for properly preparing digital technologies throughout their practices. In this way, they need more time to experiment, reflect, and dialog with other colleagues. The specialist can select the most proper digital technologies for their practice, so they are more confident and have more critical thinking to improve their teaching activities. According to [7], specialist educators/teachers "use experimentation as a means of expanding, structuring, and consolidating their repertoire of strategies" (p.30). Thus, the specialist is an innovator in their digital practices. At the last two levels of competence (C1 and C2), educators/teachers use digital technologies in their practices, both pedagogical and professional, more comprehensively and consistently. Both the leader and the pioneer have a wide range of strategies and techniques to apply in their practice. The leader knows how to select the most pertinent strategies for each pedagogical intervention, regularly reflects on and develops their digital practices, and constantly updates and dialogues with other colleagues to exchange opinions. The authors state that leading educators/teachers are considered "a source of inspiration for others, to whom they pass on their knowledge" [7, p. 30]. Pioneers question "the suitability of contemporary digital and pedagogical practices, of which they are Leaders" and, in this way, education professionals become aware of the barriers or disadvantages of these practices, to improve and innovate. Pioneers use highly complex and innovative digital technologies for their pedagogical practices. They are recognized for being innovators, for leading innovation, and for being a role model for other education professionals [7, p. 30]. In a nutshell, educators/teachers at the first two levels of competence developed by DigCompEdu, newcomer (A1) and explorer (A2), learn new information and develop basic digital pedagogical practices, at the next two levels, integrator (B1) and expert (B2), they use, expand and consider their technological practices, at the next two levels, integrator (B1) and expert (B2), they use, expand and consider their technological practices and, at the other levels, considered higher, leader (C1) and pioneer (C2), they share their knowledge with other colleagues, analyze and question their current practices, always taking into account innovation and the improvement of future practices [7]. Thus, we can see the development and progression of an educator/teacher's digital competence through the progression model outlined by DigCompEdu (see Fig. 1).

In 2022, after we had carried out our study in context, the document DigComp 2.2: The Digital Competence Framework for Citizens by Vuori-kari, Kluzer, and Punie [9] came out. This document presents DigComp 2.2 in an integrated way, highlighting new examples of knowledge, skills, and attitudes.

Portugal has also recently launched the Digital Teacher Training Program, proposed in Council of Ministers Resolution 30/2020 of April 21 [9], to integrate information and communication technologies (ICT) and other digital tools into teachers' professional

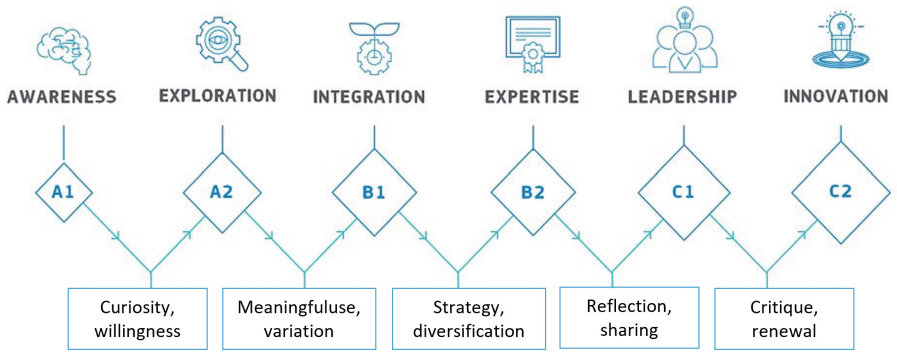

Fig. 1. DigCompEdu progress model.

and teaching practices. In addition to other aspects, the program also includes a strong commitment to training teachers, trainers from the National Qualifications System, and information technology technicians in each school, through a digital training plan for teachers, which guarantees the acquisition of the skills needed to teach in this new digital context.

2 Methodology

Data collection instruments help the process of gathering information. The questionnaire survey was the instrument that allowed us to collect important data for our research. Its main goal was to find out what educators/teachers think about the digital skills that children develop in the classroom, under adult mediation. It was divided into three parts: personal data, professional data (professional development), and data on practice (digital resources as tools to promote digital literacy). In the context of our study, it allowed us to obtain quantitative data and carry out a descriptive statistical analysis. It should be noted that in the analysis presented in this text, we have focused more on professional data. When analyzing the professional data (the second part of the questionnaire), we tried to understand how the respondents assessed themselves in terms of their digital competence when it came to using ICT; what they associated with digital literacy; whether they used ICT in an educational/school context; whether collaborative work between colleagues (if any) was carried out inside and/or outside the institution; what they thought about developing skills in this area; and what kind of participation in ICT training they had done.

3 Data Analysis

In view of the data analyzed, we note that we obtained 13 responses (3 male and 10 female respondents). Seven kindergarten teachers (53.8%) and six elementary school teachers (46.2%) took part in the questionnaire. If we look at the age range of the respondents, we can see that the majority were aged 56 or over (9 respondents - 69.2%), with the rest aged between 36 and 50 (4 respondents - 30.8%). Of the total, we would point out that

9 respondents had been teaching for more than 20 years (69.2%), while the rest chose between 5 and 10 years and between 11 and 15 years, i.e., 7.7% and 23.1% respectively.

As can be seen in Fig. 2, the professionals who took part in this questionnaire assessed their digital competence at 5 of the 6 levels of ICT use. The levels that stood out the most were B2: Specialist, with 38.5% (5 respondents), and B1: Integrator, with 30.8% (4 respondents). Next, with the same percentage of 15.4%, were level A2: Explorer and level C1: Leader, with 2 people each (see Fig. 2).

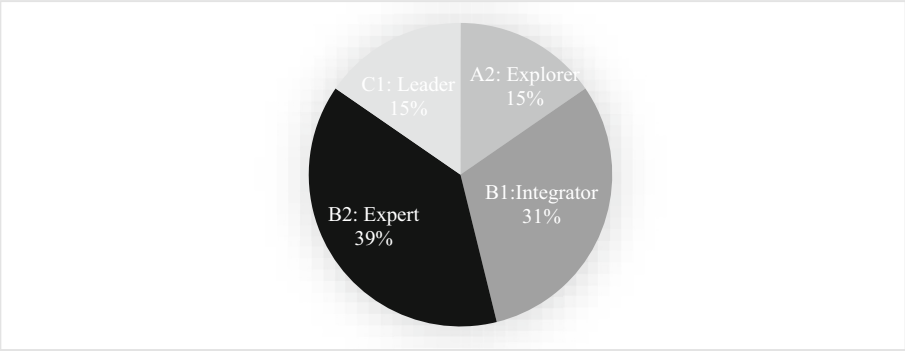

Fig. 2. Respondents' assessment of their digital competence in the use of ICT.

We considered it pertinent to understand the respondents' perception of the concept of digital literacy (see Fig. 3), associating it with the context of each of them, through 3 options to choose from: Advanced skills and knowledge (1 respondent); Instrumental skills and knowledge (7 respondents); and Attitudes towards the application of knowledge (8 respondents).

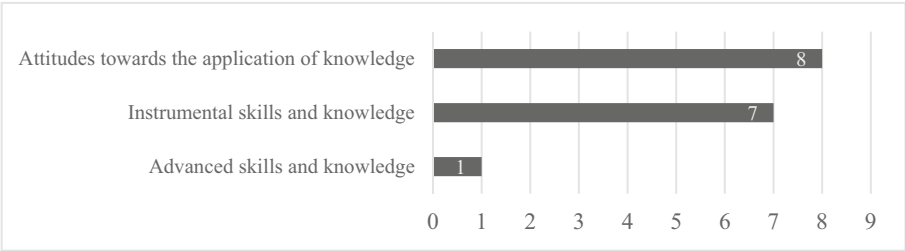

Fig. 3. Respondents' perception of the concept of digital literacy.

Bearing in mind what was said in the theoretical framework, we believe that digital literacy makes it possible to develop a set of ICT oriented skills so that they can be used and applied in various contexts, be they educational, professional, or social.

Question 3 presented five options to choose from to understand the daily use of ICT in the respondents' practice (see Fig. 4).

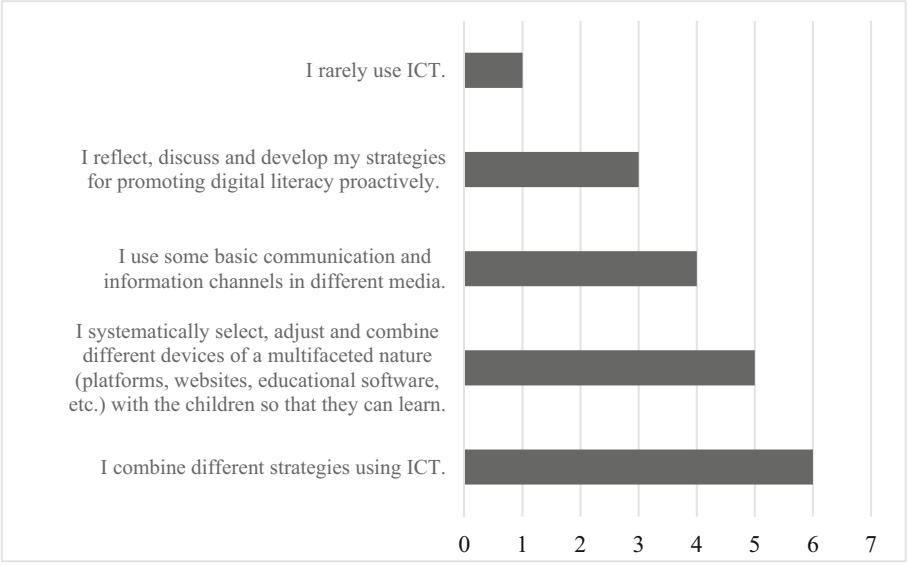

Fig. 4. Level of proficiency in the use of ICT in different educational contexts.

Given that participants could select several options, it was possible to obtain more information about the work they do in an educational/school context. Most respondents believe that they combine different strategies using ICT (46.2%). Next, the most selected option shows that respondents systematically select, adjust, and combine different devices of a multifaceted nature (platforms, websites, educational software, etc.) with children so that they can learn (38.5%). Of those surveyed, 23.1% proactively reflect on, discuss, and develop their strategies for promoting digital literacy. These three options reflect positively on the promotion of digital literacy in educational/school contexts. Even so, some respondents rarely use ICT (7.7%) or who use it only as basic communication and information channels in different media (30.8%). For these two options, it would be essential to carry out a more detailed analysis to try to understand what reason(s) led the respondents to select these two options.

The respondent who rarely used ICT in his teaching practices was in the 5 to 10 years of service bracket and considers himself to be at level B2: Specialist. When we looked at this profile, we wondered why this respondent rarely used ICT, since he rated himself as an expert, i.e., at this level of digital competence he would be expected to use ICT more often in an educational context. As we don't know the age group of the children this respondent worked with, we can say that it may be difficult to implement these practices, probably for various reasons.

Most of the respondents who reported using some basic communication and information channels in different media were aged 56 or over, and most of them had been teaching for more than 20 years. This contradicts the idea that age and years of experience impede moving from traditional to innovative teaching, as we have some examples that allow us to conclude that this is not always the case, given that these respondents

expressed a willingness to improve professionally about digital, as we will see in later analyses.

As far as collaborative work is concerned, whether it takes place outside or inside the educational institution, we can see that there is a certain amount of work going on since everyone, within the various options to choose from, collaborates and/or shares information and resources via distance means (see Fig. 5).

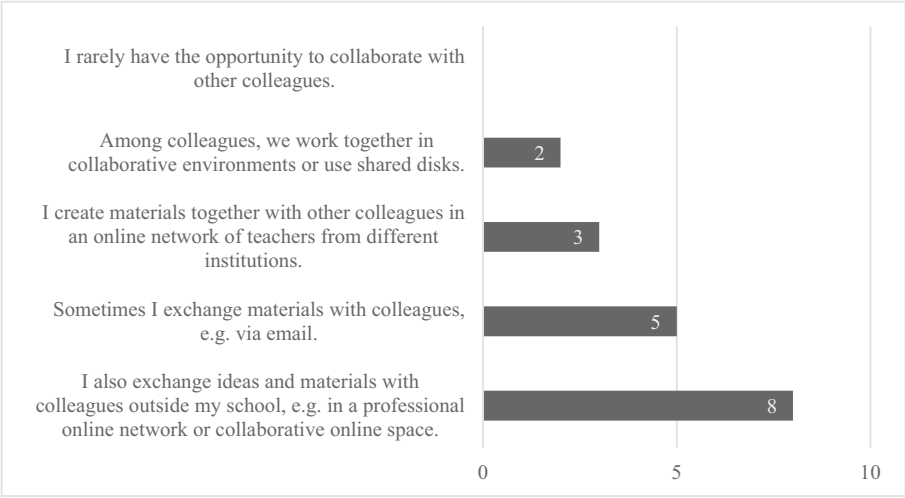

Fig. 5. Collaborative work inside and outside the educational institution.

Information enables professionals to develop and improve their teaching practices, using the ease of distance communication offered by digital technologies. Thus, through the exchange of ideas/materials and sharing networks, information becomes more accessible to everyone and more enriching, to build new digital materials to be put into practice in different educational/school contexts. In short, this peer support also allows educators/teachers to develop their digital literacy.

Another question in the questionnaire concerned the skills developed by professionals, in an active and involved way, in the field of ICT, and was related to the question previously analyzed (see Fig. 6).

Figure 6 shows that 61.5% of respondents, equally, improved their skills through reflection and experimentation, as well as developing a set of resources that enabled them to improve their ICT skills. Although the number of respondents is the same for these two options, it does not mean that they are the same, although some selected both options. Some respondents also selected the option that they discuss with their colleagues to innovate and improve their educational practice with ICT, while also noting that they help each other intending to develop their digital strategies (23.1% and 15.4% respectively).

Educators/teachers have looked to develop their digital skills, intending to improve and invest in learning and/or developing new skills with other colleagues, thus trying to ensure more challenging, active, and innovative practices.

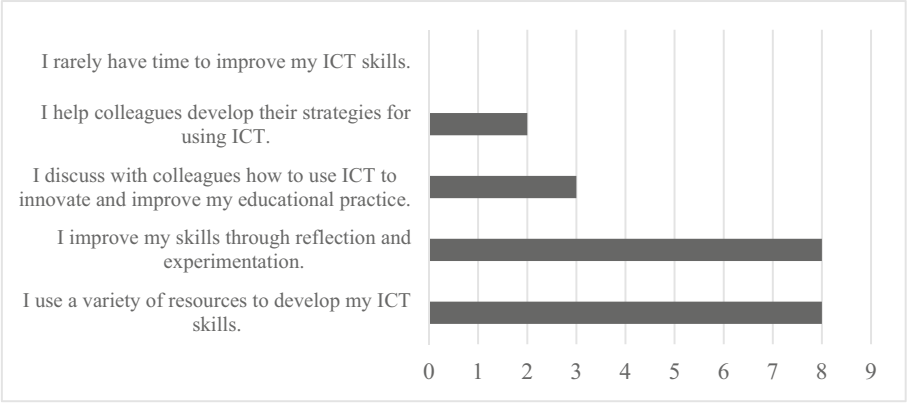

Fig. 6. Development of ICT skills in an active and involved way.

The last question was used to find out about the training courses they had taken part in, as well as their interest in attending them (see Fig. 7).

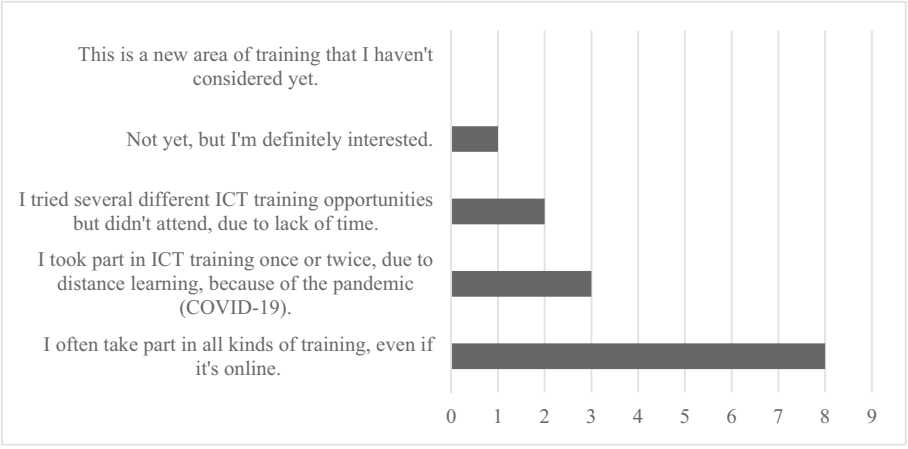

Fig. 7. Respondents' participation in ICT training.

61.5% of respondents actively taken part in all types of training, even in online format, thus showing their desire to broaden their digital knowledge. Some respondents pointed out that, due to lack of time, they were unable to attend this type of training regularly (15.4%). The pandemic caused by COVID-19, despite the constraints it has presented to educational institutions, has also led to greater adherence to digital technologies, thus requiring these professionals to (re)adapt to this new context. In this way, 23.1% of those surveyed had undergone some training to be able to respond to emergency remote teaching. Even so, some had never taken part in ICT training (7.7%), but who showed an interest in doing so, given that, when analyzing the remaining answers, we noticed that one of the respondents rated himself as an explorer (A2 level) and sought to improve his

skills through reflection and experimentation, as well as exchanging ideas and materials with other colleagues.

Compared to the earlier question, the respondents are involved in the development of their professional training, more specifically in the construction of their digital knowledge.

4 Conclusions

We believe that digital competence is one of the most important skills for lifelong learning, since digital technologies are increasingly intrinsic to human life, thus considering these digital skills and digital literacy indispensable for all citizens, according to the Official Journal of the European Union [5]. Since key competencies are related to the needs of citizens in the development of the various stages of life, such as employability and participation in society, it makes sense to list digital competencies as a basic competence, since it is becoming increasingly important to develop them.

The use of digital technologies should be included and developed in children from an early age, considering an intentional and targeted learning perspective, i.e., it should be proper and adjusted to their age group. This perspective should be explained and guided by a responsible adult (informed mediator) who aims for the child's healthy development and safety. In this vein, we highlight the importance of digital technologies for the entire educational community, in different contexts, as they enable children to learn more inclusively and innovatively, allowing them to become more entrepreneurial, critical, reflective, and curious throughout their lives, and should therefore not limit educators/teachers in their choice of strategies, techniques, and methods to reduce costs. However, although the use of these technologies is beneficial to children's teaching-learning process, it does not replace the role of the educator/teacher or the relationship between them [5].

It is becoming increasingly important to adopt digital skills that enable us to keep up with developments in the world, bringing us closer to the reality in which we find ourselves. As such, it is crucial to build/improve the knowledge, skills, and attitudes needed for everyone's personal development, as well as for inclusion in the community, with the school playing an important role in developing these skills. It is clear from the above that everyone needs to develop essential skills for their personal fulfillment and development.

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Influential Factors in Academic Satisfaction Mediated by the Usability of the LMS in University Students

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Abstract. The objective of the research was to determine which factors influence academic satisfaction in university students mediated by usability, using personalization, communication, collaboration, ease of use, and navigation as predictor variables. As a mediating variable, the usability of the LMS and the dependent variable is academic satisfaction. The methodology employed corresponds to a non-experimental research design: a sample of 384 students in southern Peru are administered an electronic questionnaire ($n = 24$; $\alpha = 0.950$ $\omega = 0.950$) using reliability and validity tests, factor analysis, and structural equation modelling. It is concluded that the LMS's usability is essential for students' academic satisfaction. Although factors such as ease of use, navigation, and customization improve the system's usability, surprisingly, they do not show a direct connection with academic satisfaction. This underscores the importance of prioritizing usability in LMSs but also suggests that academic success results from multiple interconnected factors.

Keywords: Personalization · academic satisfaction · Usability · LMS · communication and collaboration · ease of use and navigation

1 Introduction

Learning Management Systems (LMS) have emerged as pivotal elements in modern education and training. These platforms, designed to streamline and centralize learning experiences, have witnessed a surge in their adoption, reflecting the profound shift towards digital paradigms in both academic and non-academic educational environments. Particularly, e-learning has become a prominent beneficiary of this digital shift, given the versatility and scalability an LMS offers.

For organizations venturing into the e-learning domain, choosing an appropriate LMS becomes crucial. Beyond merely selecting a platform, it is imperative to leverage the full potential of its features, ensuring a more enriched learning journey for the users.

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The eventual goal is to craft an impactful and efficient learning experience that translates into tangible outcomes in knowledge acquisition and skill development.

As the prevalence of LMS grows, a consequent need emerges for its evolution. Organizations have diverse requirements, often driven by the unique needs of their learner base. Keeping pace with the rapid advancements in information technology, LMS developers now possess the tools and methodologies to craft solutions that are functional and intuitively aligned with user characteristics and preferences.

However, it is essential to note that the LMS landscape has challenges. The lack of a "one-size-fits-all" solution has been a significant problem [1] identified by prior research. Though rich in content, numerous offerings on the market often function merely as content repositories rather than holistic learning environments.

Addressing this gap, there has been a discernible shift towards adaptive learning environments [2]. Such systems prioritize the unique learning trajectories of individual users, paving the way for more personalized experiences. The significance of personalization cannot be overstated; it identifies the learners' diverse preferences, aptitudes, and needs and curates' content and strategies to meet these nuances. This perspective on the importance of personalization in enhancing learner engagement and outcomes has also been supported in other studies [3].

Integrating personalization into LMS extends beyond mere algorithmic adaptations; it demands a profound comprehension of the learner's profile. Each individual introduces a unique set of attributes regarding intellectual capability, favoured learning styles, or pre-existing knowledge. Recognizing and catering to these distinctions is central to efficient personalization [4].

Connecting personalization to system usability reveals a symbiotic association. Within the field of Human-Computer Interaction (HCI), usability serves as the epitome of user-centered design. It encapsulates the core of a user's experience with the system, enveloping facets such as intuitive design, ease of navigation, and efficient content retrieval. Astutely emphasized this relationship, illustrating how usability directly associates with a learner's grasp of e-learning platforms and their overall satisfaction [5].

Given the paramount significance of usability, it is wise for organizations to routinely evaluate and recalibrate their LMS platforms, ensuring alignment with shifting user demands. Overlooking this dimension carries substantial implications. Inadequate usability can obstruct the adoption of an LMS and undercut overall user contentment [6, 7].

Regarding implementing the LMS at a Saudi university, findings concluded that while the system is robust and well-structured, it fell short of essential usability guidelines. This accentuates the necessity for LMS platforms to refine their usability protocols perpetually, guaranteeing an inclusive experience for all user categories [8].

The escalating relevance of Learning Management Systems has instigated a comprehensive scrutiny of their utility and design. A contextual framework exists to interpret the different "dashboards" arising from learning analytics [9]. Furthermore, recent investigations underscore that content, interaction, and technological quality influence students' favourable perception of the LMS. Such perception culminates in their contentment with the given system [10].

Upon examining usability principles, it is evident that elements like system status visibility and the ability to provide error messages are pivotal [11]. However, glaring challenges exist in the design and layout of some interfaces [12]. Conversely, the LMS interface design is imperative in delivering an efficient and straightforward learning process [13]. Recent studies pinpoint various usability attributes, like ease of use, efficiency, and swift load times [14].

Another pivotal dimension is the ease of use and navigation. Perceived usability is a paramount predictor of LMS adoption [15]. Davis [16], in his Technology Acceptance Model (TAM), highlights the direct nexus between perceived utility and perceived ease of use. Further research champions the significance of intuitive and navigable design, suggesting students value the simplicity and utility of virtual classrooms.

In the domain of navigation frequency, various metrics have been delineated, such as the frequency with which a student interacts with the course's main page, forums, learning materials, and more. These metrics proffer invaluable insights into students' commitment and interest levels in their respective courses [17].

Regarding academic satisfaction, numerous studies have discerned factors and techniques aiding in forecasting students' academic performance, emphasizing the importance of integration, agency, and self-assessment [18, 19]. Moreover, it is posited that despite the abundance of available data, a clear correlation between LMS activity and academic achievement is only sometimes evident [20].

Lastly, the utility of personalized recommendation systems has been accentuated in the realm of communication and collaboration. They can be classified into three categories: content-based, collaborative, and hybrid. These systems aim to elevate the user experience by grouping items based on similarity, selection frequency, or a combination of both strategies [21–23].

Thus, usability, design, navigability, academic satisfaction, and communication and collaboration tools are cardinal facets in the deployment and success of an LMS. With technological advancements, the imperative to adapt and refine these systems becomes paramount, ensuring the caliber of online learning. Given the preliminary arguments, the following hypotheses are posited:

(H1): Communication and collaboration (CC) have a positive direct effect on academic satisfaction (SAT).

(H2): Communication and collaboration (CC) have a positive direct effect on the usability of the LMS (USA).

(H3): The ease of use and navigation (FUN) has a direct positive effect on the usability of the LMS (USA).

(H4): Personalization (PE) has a positive direct effect on academic satisfaction (SAT).

(H5): Personalization (PE) has a positive direct effect on the Usability of the LMS (USA).

(H6): The usability of the LMS (USA) has a direct positive effect on academic satisfaction (SAT).

2 Methodology

The study is based on a non-experimental, descriptive, explanatory, transversal methodology, with a sample of 384 university students of both sexes, 124 men representing 32% and 260 women representing 68%. The ages of the study units are between 16 and 29 years, with a mean of 19.43 and a standard deviation of 2.32. The sample was selected at random, and the respondents expressed their willingness to participate in the research. The study was carried out at a private university in the city of Arequipa, Peru. The instrument was specially designed for this study, with the participation of experts in computer technologies applied to education; its validation and instrument reliability tests were carried out through exploratory and confirmatory factor analysis tests, respectively. The instrument was distributed online between April and June 2023. The analysis, was carried out in statistical software for modelling equations called SmartPLS v. 4.0.

3 Results

Reliability tests were conducted using the Jamovi software (v. 2.3.13). Both the Alpha Cronbach and McDonald's Coefficient produced results of 0.94, indicating strong measurement consistency. We also conducted an exploratory factor analysis to assess the relationship between factors and their items. The initial Kaiser-Meyer-Olkin (KMO) test gave a value of 0.950, confirming excellent compatibility of the data for factor analysis. The adoption of the 'Least Residual' method alongside 'oblimin' rotation means we aimed to narrow down discrepancies between actual and estimated correlation matrices, allowing for the possibility that factors might be correlated.

The factor analysis clarified the structure of the items related to dimensions such as "Ease of Use and Navigation", "Satisfaction", "Communication and Collaboration", "Personalization" and "Usability". This clarity reinforces the validity of the questionnaire's design. A confirmatory analysis was then undertaken using covariance-based structural equation modelling (CB-SEM). The model fit indices included: RMSEA (Root Mean Square Error of Approximation): A score of 0.05, denoting an excellent model fit. Comparative Fit Index (CFI): With a result of 0.97, the model's alignment is deemed exceptional. Tucker-Lewis Index (TLI): A score of 0.97 indicates a high-quality fit, and Goodness of Fit Index (GFI): Scoring 0.99, this suggests the model almost perfectly matches the observed data.

In summary, the model consistently fits the data exceptionally well. Both relative (CFI and TLI) and absolute (RMSEA and GFI) indices confirm that the model mirrors the patterns in the actual data. This consistency between the proposed model and empirical findings underscores the model's validity.

Based on the data in Table 1 about the reliability indices, we began to define the quality criteria: α (Cronbach's Alpha): It is a measure of internal consistency of the items of a measurement instrument. Values greater than 0.70 generally indicate good reliability. ω_1, ω_2, and ω_3 (Omega Coefficients): They are alternative measures to Cronbach's Alpha that indicate the instrument's reliability. Like the Alpha, values greater than 0.70 indicate good reliability and AVE (Average Variance Extracted): Represents the variance a construct captures of its indicators with the amount of variance due to

Table 1. Reliability indices.

Variable	α	ω	AVE
FUN	0.87	0.87	0.57
CC	0.88	0.87	0.58
PE	0.86	0.87	0.62
SAT	0.85	0.85	0.59
USA	0.83	0.83	0.62

measurement error. Values greater than 0.50 indicate good convergence of the construct items. The constructs evaluated in the study (Ease of Use and Navigation, Communication and Collaboration, Personalization, Satisfaction and Usability) present robust reliability indices, all exceeding the recommended threshold of 0.70. In addition, the AVE values for each construct exceed the standard of 0.50, indicating that the items adequately measure their respective constructs. These results underscore the quality and reliability of the instruments used in the study.

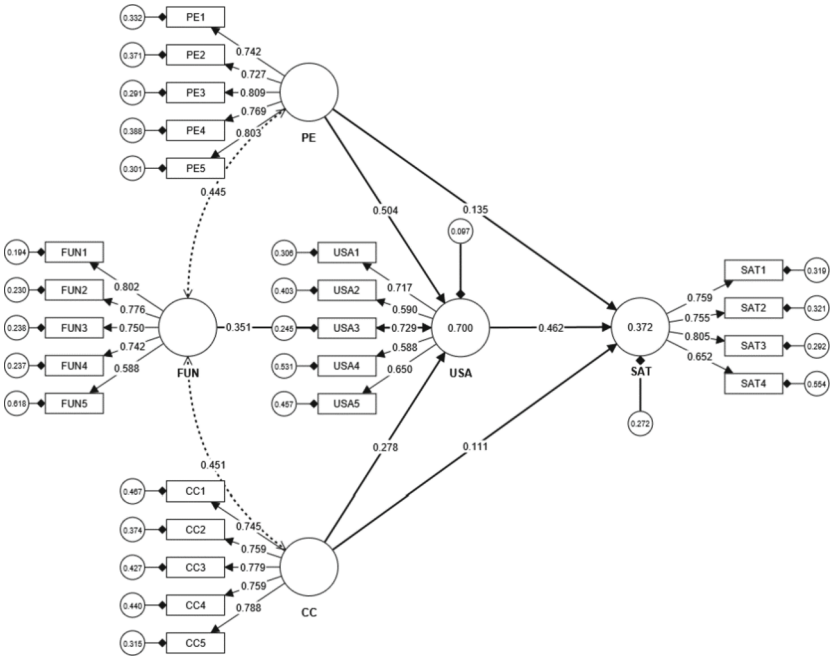

Fig. 1. Path Model CB-SEM.

Figure 1 describes the relationship between the independent and dependent variables. The R^2 (R-square) values represent the variance explained by the independent variables in a model concerning the dependent variable. In other words, R2 is a measure that tells

us how much of the variability of the dependent variable is explained or predicted by the independent variables in the model. Within the context of this research:

SAT (Academic Satisfaction): An R2 of 0.372 suggests that approximately 37.2% of the variability in academic satisfaction (SAT) is explained by the variables that were included in the model (e.g., LMS usability, personalization, communication and collaboration, among others). The remaining percentage (62.8%) could be due to other factors not included in the model, measurement errors, or inherent variability.

USA (LMS Usability): An R2 of 0.700 indicates that 70% of the variability in the perception of LMS usability (USA) is explained by the variables considered in the model (such as ease of use and navigation, customization, and communication and collaboration). This suggests a fairly robust model regarding usability since most of its variability is explained by the variables the researcher considered.

These data reflect the ability of the proposed model to explain the variability in the dependent variables. In particular, the model is exceptionally robust in its ability to explain variability in LMS usability. However, although 37.2% is a considerable proportion in social and educational research for academic satisfaction, there is still a substantial percentage of unexplained variability, which may invite researchers to explore other factors or dimensions that could influence satisfaction. Academic in future research.

Table 2. Path coefficients

Hypothesis	Parameter estimates	Standard errors	T values	P values
(H1) CC -> SAT	0.096	0.080	1.196	**0.233**
(H2) CC -> USA	0.207	0.055	3.748	0.000
(H3) FUN -> USA	0.337	0.064	5.303	0.000
(H4) PE -> SAT	0.140	0.116	1.206	**0.229**
(H5) PE -> USA	0.449	0.068	6.606	0.000
(H6) USA -> SAT	0.536	0.135	3.972	0.000

Based on the data in Table 2, which examines the relationship between various components of the Learning Management System (LMS) and academic satisfaction, significant findings were found that shed light on how certain aspects of the LMS can influence student perception. From the path coefficients obtained, it is observed that "Communication and Collaboration (CC)" does not have a significant effect on "Academic Satisfaction (SAT)", with an unstandardized coefficient of 0.096 and a p-value of 0.233. Similarly, although "Personalization (PE)" shows a positive relationship with SAT (coefficient = 0.140), this relationship is also not statistically significant (p = 0.229). These results suggest that while these two factors may influence academic satisfaction, their impact needs to be more conclusive in the context of this study.

However, where we find robust evidence is in the relationship between "LMS Usability (USA)" and "Academic Satisfaction (SAT)". An increase in the usability of the LMS

is strongly associated with an improvement in academic satisfaction, with a coefficient of 0.536 and a practically null p-value.

Additionally, both "Ease of Use and Navigation (FUN)" and "Personalization (PE)" showed to have a significant influence on the "LMS Usability (USA)", with coefficients of 0.337 and 0.449, respectively, and both with insignificant p values. These results support the notion that greater ease of use and navigation, and personalized features in the LMS can substantially improve students' perceived usability.

Finally, it is essential to highlight that although "Communication and Collaboration (CC)" did not directly impact academic satisfaction, it did have a significant effect on "LMS Usability (USA)" with a coefficient of 0.207 and a negligible p-value. This could indicate that, although communication and collaboration do not directly translate into greater satisfaction, they contribute to a perception of more excellent usability of the LMS.

The research context explored multiple interconnected dimensions of the Learning Management System (LMS) and its influence on the student's academic experience. Through a meticulous evaluation of the interrelationships between these dimensions, several fundamental hypotheses were outlined.

(H1): It postulated that the "Communication and Collaboration (CC)" dimension exerted a palpable influence on "Academic Satisfaction (SAT)". Empirical evidence did not provide sufficient support for this assertion. Although a positive trend was observed, the degree of certainty ($p = 0.233$) did not reach the conventional thresholds for statistical confirmation. (H2): It suggested an intrinsic relationship between "Communication and Collaboration (CC)" and the perception of "LMS Usability (USA)". The data robustly supported this conjecture, reaching a degree of certainty that rules out chance ($p = 0.000$).

(H3): It stated that "Ease of Use and Navigation (FUN)" was intrinsically linked to "LMS Usability (USA)". Empirical tests supported this relationship strongly, highlighting a significant correlation with statistical certainty ($p = 0.000$). (H4): Theorized that "Personalization (PE)" directly influenced "Academic Satisfaction (SAT)". In this context, the data did not provide the necessary support for this hypothesis. Although a positive slope was detected, the associated certainty ($p = 0.229$) did not allow for definitive confirmation.

(H5): Proposed that "Personalization (PE)" was closely linked to "LMS Usability (USA)". This relationship received considerable support, evidenced by a level of certainty that excludes the possibility of chance ($p = 0.000$). (H6): It established that "LMS Usability (USA)" played a central role in "Academic Satisfaction (SAT)". This premise was decisively corroborated by the evidence collected, with a highly significant level of certainty ($p = 0.000$).

Thus, of the interrelationships theorized in the study, four of them have a solid empirical foundation. On the other hand, two of these hypotheses require further exploration, given that statistical confirmation was not achieved in this particular context. It is imperative to note that the lack of confirmation does not denote the absence of a relationship but may indicate the inherent complexity of the phenomenon studied or the particularities of the research design.

4 Conclusions

According to the results obtained in the study about the Learning Management System (LMS) and its influence on the student's academic experience, it is undeniable that specific components of the LMS have a marked impact on both the perception of the system's usability and academic satisfaction. The "Usability of the LMS" stands out as a fundamental pillar in this relationship, exerting a direct influence on "Academic Satisfaction" and, in turn, being shaped by other significant dimensions, such as "Ease of Use and Navigation" and "Personalization".

However, it is surprising to note that, despite their theoretical relevance, both "Communication and Collaboration" and "Personalization" did not establish a direct and robust connection with "Academic Satisfaction" in this particular study. This observation leads us to reflect on the multifaceted nature of learning and the academic experience, where specific components can play indirect roles but still be vital in the educational ecosystem.

These discoveries highlight the importance of conceiving and structuring learning management systems that prioritize usability as one of their foundations, thus providing students with a more enriching and satisfactory academic experience. However, it is imperative to recognize that a holistic perspective is required in the complex mosaic of the educational environment and in the face of the heterogeneity of student needs. In this panorama, usability emerges as an essential component but not as the only catalyst for academic success. These findings invite us to continue exploring and understanding the subtleties that define a quality educational experience, maintaining a balance between technology, pedagogical methodologies and students' individual needs.

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Social Networks as Predictors in Purchasing Decisions, Mediated by Personal Factors in University Students

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Abstract. The objective of the research was to determine the role of social networks as predictors of purchasing decisions mediated by social factors. A non-experimental research design was used in the methodology, which involved a sample of 184 university students in southern Peru ($n = 24$; $\alpha = 0.940$ $\omega = 0.940$), an electronic questionnaire, reliability and validity tests, factor analysis, and the modelling of structural equations based on covariances. It is concluded that a direct and robust relationship exists between psychological factors and the purchase decision, meaning variations in psychological predispositions significantly influence it. Instagram shows an even more significant influence than Facebook on the purchase decision, and social factors do not mediate between the model's predictor variables and purchase decisions.

Keywords: Facebook · Instagram · Tiktok · social factors · psychological factors · purchase decision

1 Introduction

Social media has emerged as a powerful tool of influence, especially among younger generations. In the university community, these digital platforms have become ubiquitous, acting as "social barometers" that guide the perception and acceptance of products and brands. Social networks can trigger positive and negative emotions, depending on the use they are given [1, 2].

The predictive role of social networks in purchasing decisions has been widely discussed. Social media can directly influence students' decisions due to the prevalence of "influencers" and the perception of authenticity that their recommendations carry with them.

However, there is growing discussion about the mediating role of personal factors. Internal factors like the consumer's personality, beliefs, and prior experiences also significantly impact their purchasing decisions, in addition to social media recommendations.

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The digital era has transformed communication and marketing, with social networks at the epicentre of this evolution. As one of the first major platforms on the scene, Facebook has laid the foundation for this revolution. "Reliance on social media as an effective online communication platform… Connects people with other individuals" [3]. In this line of work, Facebook has been a crucial tool to establish and strengthen connections between companies and consumers. Social media facilitates interactive communication between entrepreneurs and anyone [4], in the same way that education promotes collaborative learning [5], a concept that Facebook has taken advantage of for years.

Although it has been recognised later than Facebook, Instagram has been recognised for its focus on visual content, which has directly influenced purchasing decisions. The platform has opened up opportunities for brands to showcase their products in an attractive and aesthetically pleasing way. Social media is considered a problem solver due to its feature of sharing and creating functional knowledge [6], and this is evident in the way Instagram allows brands and consumers to share experiences and recommendations.

On the other hand, TikTok has been the fastest-growing platform in recent years, especially among youth. However, there is still vast research potential in psychology and psychiatry. With its unique format and focus on short video content, this platform has offered a new way of approaching the consumer, especially the younger generation [7].

These platforms have significantly influenced the overall picture of purchasing decision-making. When purchasing, a consumer will go through several stages [8]. These stages are intrinsically linked to the presence and participation in social networks such as Facebook, Instagram and TikTok, which are crucial in forming brand perception and awareness [9].

These three social media platforms have profoundly reshaped marketing and consumer behaviour in the digital age. Understanding their impact and how they interrelate with purchasing decisions is essential to develop effective marketing strategies.

Psychological factors are essential to understanding consumer behaviour and decisions in various areas. These factors encompass a series of intrinsic variables that influence how people perceive, interact and respond to different situations and stimuli. Psychological factors play a crucial role in forming brand awareness. Brand perception is critical as it dictates how consumers view and understand a brand [9]. Various marketing campaigns, past experiences with the brand, or the opinions and recommendations of others can influence this perception.

In the field of data science and persuasion, it is crucial to identify the key variables that can influence the attitudes and behaviours of the target audience. Psychological factors occupy a prominent place within these variables since how people interpret and process information can vary depending on their psychology [10]. The choice of clothing, specifically Muslim clothing in the context provided by Daga, R. and Andi Jenni Indriakati Daga, R. y Andi Jenni Indriakati [11], s not only a decision based on religious or social factors. Psychological factors, such as personal motivation, learning and previous experiences, can also influence this choice.

Psychological, economic, and social factors can influence consumers' decision to purchase more affordable food products [12]. This behaviour may be triggered by psychological and social factors such as perceived value, financial security, and self-esteem.

However, the literature on panic buying is limited. Anxiety, fear, and perceptions of scarcity explain how psychological factors can drive people to act non-habitually [13]. Psychological factors encompass various intrinsic elements that determine how individuals react to stimuli, products or situations. Understanding these factors is essential to designing marketing strategies, understanding purchasing behaviours, and developing effective interventions in various areas.

The purchasing decision is an intricate process that involves multiple stages and is influenced by a number of both internal and external factors. Consumers go through different phases when deciding which product or service to purchase, and this complexity has been reflected and discussed in various academic research. A consumer purchases a good or service after a certain threshold of time. This threshold is influenced by consumer expectations based on critical market conditions [14].

The purchase decision takes time; a consumer goes through several stages before deciding, from searching for information about the product or service to considering alternatives to purchasing [15]. Perceived quality is critical to purchasing decisions, mainly through platforms like Instagram. This perceived quality, part of brand equity, substantially impacts brand recognition [16]. Likewise, there are both internal and external factors that affect the purchasing decision. While the internal ones include beliefs, attitudes and perceptions, the external ones cover culture and social class [17].

On the other hand, frequent purchasing decisions are linked to low self-esteem. People with this profile often seek to validate themselves and feel better by purchasing products promoted by public figures [18]. The purchasing decision is a problem-solving process. It consists of recognizing needs and desires, searching for information and selecting purchase alternatives considering various aspects of the product [19]. There are six dimensions to measure the purchase decision, including product selection, brand, purchase channel, purchase time, quantity, and payment method [20].

Regarding product quality and decision, it is stated that product quality has a significant and positive effect on purchasing decisions, either directly or indirectly through brand image [21]. Likewise, purchasing decisions are influenced by attractive marketing campaigns that capture the consumer's attention. The presence of interest arises once the consumer has access to relevant data [22].

The purchasing decision is a complex combination of cognitive, emotional, social and situational factors. Understanding this process is essential for brands and companies that seek to influence consumer behaviour effectively; therefore, the validity of influencer marketing is recognized due to the division of traditional and digital media, which always seeks niches. More specific market conditions [23]. Given the preliminary arguments, the following hypotheses are posited:

H1 Psychological Factors (FPS) positively influence the Purchase Decision (FC).

H2 Psychological Factors (FPS) have a statistically significant effect on Social Factors (FS).

H3 Social Factors (FS) positively influence the Purchase Decision (FC).

H4 Facebook (ITF) directly and positively impacts the Purchase Decision (FC).

H5 Facebook (ITF) positively influences Social Factors (FS).

H6 Instagram (ITI) has a statistically significant effect on the Purchase Decision (FC).

H7 Instagram (ITI) directly and positively impacts Social Factors (FS).
H8 Tiktok (ITT) positively influences the Purchase Decision (FC).
H9 Tiktok (ITT) has a statistically significant effect on Social Factors (FS)

2 Methodology

The research was carried out using a non-experimental, descriptive, explanatory and cross-sectional approach, analyzing 184 university students, of which 53 were men (34%) and 101 women (66%). These students were between 20 and 30 years old, with an average of 23.85 years and a variability of 2.86 years. The study participants were selected randomly and willingly participated in research conducted at a private institution in Arequipa, Peru. A specific instrument was designed with the help of educational technology specialists, which was subsequently validated and tested in terms of reliability through exploratory tests and factor analysis. The questionnaire was shared online between May and June 2023, and the collected data was analyzed using SmartPLS v software. 4.0.

3 Results

Reliability tests were carried out. Both Cronbach's Alpha and McDonald's Coefficient returned a value of 0.94, demonstrating excellent consistency in measurement. Furthermore, we conducted an exploratory factor analysis to understand the relationship between factors and their respective items. The initial Kaiser-Meyer-Olkin (KMO) test showed a value of 0.88, which validates the suitability of the data for factor analysis. The choice of the 'Least Residual' and 'oblimin' rotation methods seeks to reduce the differences between the actual and estimated correlation matrices, admitting that the factors could be correlated.

The factor analysis clarified the structure of the items about dimensions such as "Facebook", "Instagram", "Tiktok", "Social Factors", "Psychological Factors", and "Purchase Decisions". This reinforces the validity of the questionnaire design. Subsequently, a confirmatory analysis was performed using covariate-based structural equation modelling (CB-SEM). Model fit indices included RMSEA with a value of 0.08, indicating good model fit. Comparative Fit Index (CFI) with a result of 0.90, showing good alignment of the model. The Goodness of Fit Index (GFI) has a value of 0.93, which suggests that the model agrees almost perfectly with the observed data.

Based on the data presented in Table 1, it is evident that the majority of variables exhibit strong reliability and convergence. The measure of internal consistency, denoted by α (Cronbach's Alpha), consistently shows values well above the accepted threshold of 0.70 for most variables, indicating that the items within these constructs are coherent and measure the intended concept effectively. This consistency is further corroborated by the ω (Omega coefficients) values, which largely mirror the α results, solidifying our confidence in the instrument's reliability.

The AVE (Extracted mean-variance) scores offer insights into the convergence of the construct's items. Generally, the higher the AVE, the more a factor is explained by its items, and with values predominantly over the 0.50 benchmark, it is clear that these

Table 1. Reliability indices.

Variable	α	ω	AVE
ITF	0.91	0.91	0.67
ITI	0.88	0.88	0.64
ITT	0.85	0.85	0.65
FPS	0.85	0.86	0.54
FS	0.70	0.67	0.52
FC	0.79	0.79	0.57

constructs capture a substantial amount of variance from their indicators, minimizing the variance due to measurement error. Even for variables like FS, which hovers around the lower end of the spectrum in both α and ω, the AVE still means a good convergence of its items.

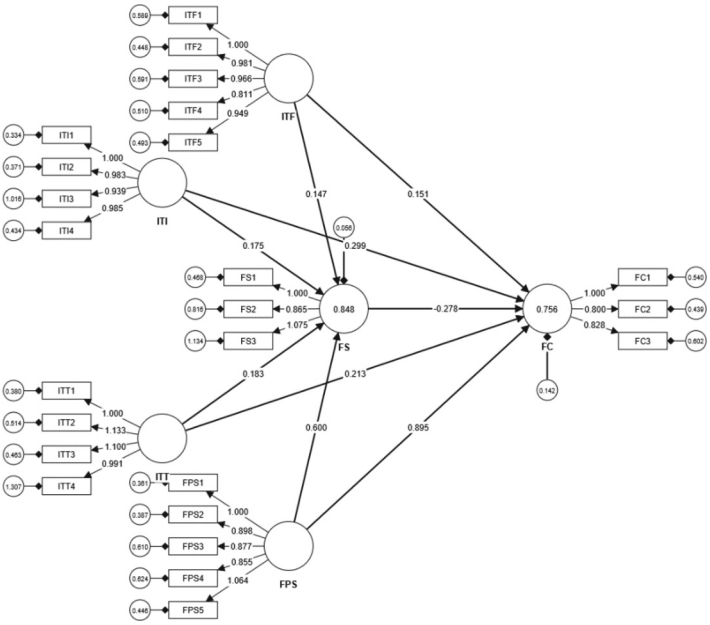

Fig. 1. Path Model CB-SEM.

Figure 1 illustrates the connection between the independent and dependent variables. The R^2 (R-square) values reflect the amount of variance the independent variables account for in a model relative to the dependent variable. In simpler terms, R^2 is an indicator that reveals the extent to which the variability of the dependent variable can be predicted or accounted for by the independent variables in the given model. Within this research's framework:

FC (Purchase Decision): An R^2 of 0.756 indicates that around 75.6% of the variability in the Purchase Decision can be attributed to the variables integrated into the model. The residual percentage (24.4%) The model may not account for other factors, measurement errors, or natural variability.

FS (Social Factors): An R^2 of 0.848 suggests that 84.8% of the variability in the social factors is elucidated by the variables incorporated in the model. This denotes a reasonably comprehensive model in terms of its applicability since a significant portion of its variability is clarified by the variables the investigator has considered.

Table 2. Specific indirect effects (standardized) Mean, STDEV, T values, p-values

Mediation relations	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T values	P values
FPS -> FS -> FC	−0.175	−0.335	1.261	0.139	0.890
ITF -> FS -> FC	−0.059	−0.084	0.357	0.165	0.869
ITI -> FS -> FC	−0.063	−0.099	0.445	0.142	0.887
ITT -> FS -> FC	−0.057	−0.108	0.429	0.132	0.895

According to Table 2's results, the mediation effects of social factors (SF) are presented. FPS -> FS -> FC: It is suggested that psychological factors (FPS) could influence the purchase decision (FC) through social factors (FS). However, the p-value of 0.890 indicates that this indirect effect is not statistically significant at the traditional 0.05 level. ITF -> FS -> FC: It is being analyzed whether the use of Facebook (ITF) influences the purchase decision (FC) through social factors (FS). With a p-value of 0.869, this mediation is also not significant. ITI -> FS -> FC: Here, we are investigating whether the use of Instagram (ITI) affects the purchase decision (FC) mediated by social factors (FS). Again, the p-value of 0.887 indicates that it is not significant. ITT -> FS -> FC: Finally, we examine whether TikTok (ITT) influences the purchase decision (FC) through social factors (FS). With a p-value of 0.895, this relationship is also not significant.

Based on the results and using a traditional significance threshold of 0.05, there does not appear to be a significant mediation effect of social factors (SF) on the relationship between social media platforms or psychological factors and purchase decisions (CF). In other words, social factors are not a significant channel through which social media platforms or psychological factors influence the purchase decision.

Based on the data in Table 3, Within the SEM framework, the magnitude and direction of the standardized coefficients (β) provide crucial insight into the nature and significance of the proposed relationships. Regarding hypothesis 1: FPS -> FC: The standardized coefficient of 0.764 suggests a direct and robust relationship between Psychological Factors (FPS) and the Purchase Decision (FC). The t value of 6.747, which significantly

Table 3. Total effects (standardized) Mean, STDEV, T values, p values

Relationships Hypothesis	Path Coefficient (β)	Sample mean (M)	Standard deviation (STDEV)	T values	P values	Results
H1: FPS -> FC	0.764	0.741	0.113	6.747	0.000	Supported
H2: FPS -> FS	0.793	0.770	0.138	5.745	0.000	Supported
H3: FS -> FC	−0.221	−0.403	1.457	0.152	0.880	Rejected
H4: ITF -> FC	0.158	0.155	0.080	1.980	0.048	Supported
H5: ITF -> FS	0.267	0.268	0.108	2.470	0.014	Supported
H6: ITI -> FC	0.326	0.340	0.129	2.536	0.012	Supported
H7: ITI -> FS	0.287	0.305	0.129	2.222	0.027	Supported
H8: ITT -> FC	0.181	0.194	0.112	1.621	0.106	Rejected
H9: ITT -> FS	0.257	0.270	0.127	2.026	0.043	Supported

exceeds the generally accepted critical threshold (e.g., $t > 1.96$ for $p < 0.05$ in a two-sided test), and a p-value of 0.000 corroborate this relationship as statistically significant. This could imply that variations in FPS predominantly influence purchasing decisions.

Hypothesis 2: FPS -> FS: With a coefficient of 0.793, the relationship between FPS and Social Factors (FS) is also positive and strong. This result suggests that psychological predispositions are relevant in shaping social factors or perceptions in a consumption context. Hypothesis 3: FS -> FC: Despite having a negative coefficient (–0.221), indicating an inverse relationship, the p-value of 0.880 reveals that this relationship is not statistically significant. This could suggest that, although Social Factors can influence the Purchase Decision, other factors (such as psychological factors) could be more determined in this study.

For hypothesis 4: ITF -> FC and hypothesis 5: ITF -> FS: The presence of Facebook (ITF) in the model suggests a positive but moderate influence on both the Purchase Decision and the Social Factors, with coefficients of 0.158 and 0.267, respectively. These coefficients, together with the corresponding p-values, underline the relevance of Facebook in the purchasing decision-making process and its interaction with social factors. Hypothesis 6 and 7: ITI -> FC and ITI -> FS: Instagram (ITI) shows a more pronounced influence on the Purchase Decision and Social Factors compared to Facebook, but less than FPS. This reinforces the notion that different social media platforms can impact consumer behaviour differently. Regarding hypothesis 8 and 9: ITT -> FC & ITT -> FS: While TikTok (ITT) has a statistically significant relationship with Social Factors, its relationship with Purchase Decision is not significant. This could indicate that TikTok

may influence consumer social perceptions but does not directly impact the purchase decision within this study.

4 Conclusions

According to the results obtained in the study, there is a direct and robust relationship between psychological factors and purchasing decisions, which means that variations in psychological predispositions significantly influence consumers' purchasing decisions. Psychological factors also play an essential role in shaping social factors in consumption, indicating that an individual's psychological predispositions can determine how they perceive or interact with their social environment. However, although social factors seem to influence the purchase decision, this relationship is not statistically significant, suggesting that other factors, such as psychological ones, have a more pronounced impact. Regarding the influence of social media platforms, Facebook has a positive impact on both the purchasing decision and social factors, highlighting the relevance of this platform in the consumer decision-making process and its influence on the social environment.

On the other hand, Instagram shows an even more significant influence than Facebook on purchase decisions and social factors. While influencing consumers' social perceptions and attitudes, TikTok does not directly impact their purchasing decisions. Overall, social media's influence on purchasing decisions and social factors is multifaceted and varies by platform. Marketers and businesses must recognize these nuances and adapt their strategies based on their target platform and audience. This study sheds light on the complex interplay between psychological predispositions, social media platforms, and social factors in purchasing decision-making. It provides invaluable insight for optimising their social media presence and strategies.

Mediation analysis is essential to understand how and why certain factors influence a specific decision or behaviour. In this study, we explored whether Social Factors acted as a bridge between social media platforms and psychological factors and how these influence the purchase decision. The results indicate that although social media platforms and psychological factors are important in themselves, they do not exert their influence through Social Factors in regards to the purchase decision. In other words, Social Factors do not act as a critical channel through which the influence of social networks and psychological factors on decision-making is transmitted. It is as if people were making their purchasing decisions influenced by platforms such as Facebook, Instagram, or TikTok and their own psychological predispositions, but not necessarily by the perception or influence of their social environment.

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Wedo 2.0 and Lego Education for the Logical Development of Elementary School Children

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Abstract. In order to address the limited interest of children in the area of mathematical logic, this article presents strategies aimed at enhancing the logical thinking of elementary school students. To achieve this goal, innovative educational tools were employed, specifically, Wedo 2.0 and Lego Education, which combine Lego figures with block-based programming. The motivation behind this approach is rooted in the ability of Lego objects to captivate students' attention due to their versatility in terms of colors, shapes, and sizes. By combining these figures with block-based programming, an interactive and stimulating learning environment is created that fosters creativity and the development of logical and mathematical skills. The research methodology used was quantitative and descriptive, and the target population consisted of fourth-grade students at the Oswaldo Guayasamín Educational Unit in Ecuador. The students were divided into two parallel groups, totaling 42 participants. The results of this study revealed a positive impact on the development of students' logical thinking. The experimental group experienced a significant increase in their average scores, moving from an initial level ranging from low to medium to a medium-high level, with an average score of 6.66. In conclusion, the implementation of educational strategies that combine Wedo 2.0 and Lego Education proved to be effective in improving the logical thinking and mathematical skills of elementary school students.

Keywords: logical thinking · strategy development · mathematics teaching

1 Introduction

Currently, the world is heavily influenced by technology, where people coexist with and use these means to communicate, work directly with digital whiteboards, blogs, platforms, etc. The digital era is simply present in everything we see, touch, and use.

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This master's work is grounded in the research area of pedagogical innovation in society, specifically in education in our country. In the educational field, the pandemic forced the implementation of platforms and tools to facilitate communication between teachers and students. Children have a significant advantage because they are digital natives; hence, receiving technology-based classes is not difficult for them. However, there is still a weakness in logical reasoning that is not adequately developed.

Robotics is a discipline that has gained ground in the labor market and has also entered the field of education, known as educational robotics. In this field, students start at very young ages without difficulties in interactive programming. "Educational robotics is a new interdisciplinary teaching system that covers different curriculum areas and enables active learning by students through mechanical, electronic, and technological devices or tools" [2]. For children, robotics offers a variety of accessories and tools for building, programming, and executing simple tasks, which greatly aid interdisciplinary learning and, above all, logic.

The importance of addressing this problem is supported by the words of the renowned developmental psychologist Piaget, who emphasized the need to cultivate logical thinking in children. According to Piaget, "logical reasoning is an essential skill that lays the foundation for effective understanding and learning." Piaget's statement highlights the importance of developing logical thinking from an early age and underscores that this skill is essential in today's society, characterized by the need for informed decision-making and solving complex problems. Furthermore, the theorist Vygotsky argued that collaborative learning and social interaction play a critical role in the cognitive development of children. In his own words, "learning becomes a fundamental part of the culture and society in which we are immersed". This suggests that interaction with peers and active participation in stimulating learning environments are fundamental to the development of logical thinking in students.

In this research, innovative educational tools were employed, such as Wedo 2.0 and Lego Education, which combine Lego figures with block-based programming to create an interactive and stimulating learning environment, in line with the theoretical premises of Piaget and Vygotsky. The choice of these tools was based on their ability to capture students' attention due to the versatility of Lego figures and their potential to foster creativity and the development of logical and mathematical skills. Furthermore, this study is grounded in the conviction that, in a constantly changing and increasingly digital world, it is imperative to promote the development of logical thinking in students.

Throughout this article, the methodology used will be presented in detail, including the description of the participants, the materials and resources used, and the research procedure. Subsequently, the study's conclusions will be discussed, emphasizing the feasibility and effectiveness of incorporating technological tools into the teaching of mathematics and the development of logical thinking in students. In summary, this article offers a comprehensive view of how technology, creativity, and innovative methodologies can contribute to strengthening logical and mathematical skills in the current educational environment.

2 Related Work

In this part of the article, the work related to the research area will be presented.

Piaget highlights the role of play as: "experience and social transmission in cognitive development, valuing the importance of cooperation and cognitive conflict that arise when children interact in educational activities as a means to facilitate cognitive and moral development". [6]. Then, the best way for students to learn to solve problems is experimenting, testing, erring and correcting, LEGO is a Danish company and brand of toys recognized worldwide mainly for its interconnectable plastic blocks, nowadays it has been evolving since its foundation (1932) now the toys have the ability to interconnect and give movements of its parts through interactive programming, the official LEGO website says: "Lego Education is a new solution for Primary Education that awakens students' interest in learning STEAM subjects through playful problem solving accompanied by storytelling and thus prepares them to become persevering and independent thinkers." [7].

The Unidad Educativa Fiscal Oswaldo Guayasamín del Ecuador, in the school year 2020–2021, after analyzing the learning of elementary school students, obtained a score of 7.80 in the area of mathematics, which corresponds to basic essential, logic being one of the biggest problems that students have when they require the solution to the problems presented. An alternative is to promote robotics as a teaching-learning method for younger children; in this way, logic will be developed as a skill that can be used in the academic and professional future [8].

Logical thinking is the capacity of students who develop and are associated with the concepts of mathematical logical reasoning, understanding and exploration, enhancing abstract aspects of thinking; children of the Unidad Educativa Fiscal Oswaldo Guayasamín have insufficient mathematical logical skills, students require new strategies to acquire skills and abilities that will be very helpful in their personal and professional development, children at an early age have the need to make decisions that help improve their logical thinking [9].

The method that can be used is educational robotics, currently the LEGO company has a product that is used to develop logic through programming blocks, then, the student analyzes, builds, programs and executes. The pieces that are joined together can form objects that are capable of performing movements that depend on the programming that is done, in this case WEDO 2.0, children using intelligent electronic devices are able to analyze the code for block programming as it does not require extensive knowledge in coding.

3 Methodology

For the present work, a quantitative and descriptive type of research was applied because the properties and characteristics of the problem to be solved were compiled, obtaining the documentation of the causes and effects of the phenomenon under study in the Oswaldo Guayasamin Educational Unit of Ecuador. The modality of this research is applied, starting from the proposed theoretical framework to then design the instruments to be applied. With this, the required information is obtained from the population to

describe the phenomenon under study, analyze it and reach the conclusions that allow establishing a proposal to solve the problem found.

3.1 Participants

The research involved two sample groups of participants from the Oswaldo Guayasamín Educational Unit in Ecuador. The experimental group, consisting of 22 fourth-year General Basic Education students, engaged with LEGO Education and WEDO 2.0 to boost logical skills. The control group, with 20 students of the same level, received regular classes without these tools. Both groups underwent tests and questionnaires to evaluate logical reasoning, allowing for a comparison of the proposal's impact on the experimental group versus the control group.

3.2 Materials and Resources

Throughout this study, a variety of materials and resources were utilized for the educational proposal and data collection. Notably, the LEGO Education and WEDO 2.0 educational kits, featuring specially designed LEGO blocks and programmable sensors, played a central role. These kits were instrumental in allowing students to construct models and develop basic programming skills. Additionally, custom questionnaires were designed to assess students' logical reasoning levels, serving as a crucial tool for measuring progress in both the experimental and control groups at the research's outset and conclusion.

Furthermore, digital resources such as interactive presentations and online educational materials were integrated to enhance teaching and learning in conjunction with the LEGO Education and WEDO 2.0 kits, as illustrated in Fig. 1.

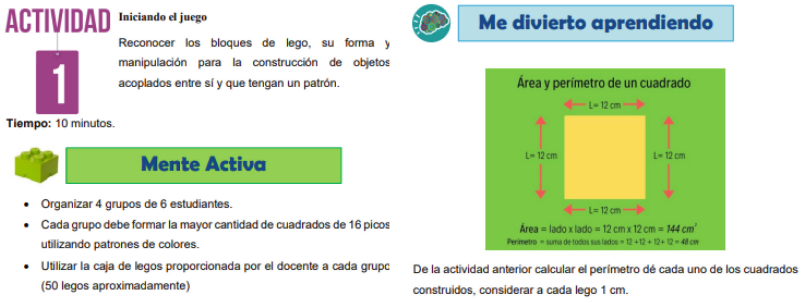

Fig. 1. Interactive activities proposed within the digital resources designed.

The research also benefited from the availability of electronic devices, such as laptops or tablets, which facilitated the programming and control of the models built with LEGO and WEDO 2.0. These technological tools allowed for a more dynamic interaction of the students with the technology. Likewise, the school infrastructure provided by the Oswaldo Guayasamín Educational Unit, including classrooms, furniture and support

resources, played a vital role in the effective implementation of educational activities. It should be mentioned that the active cooperation of school authorities and the commitment of teachers were essential factors for the successful implementation of the proposal.

3.3 Procedure

The data collection process for this research began by identifying the target population, which consisted of students in the fourth year of general education at the Oswaldo Guayasamín Educational Unit in Ecuador. The study aimed to assess the application of LEGO Education and WEDO 2.0 in developing logic in EGB children. The research involved designing instruments for data collection and validating their reliability. Since the population was finite, a specific sampling calculation was not applied. The students in this group were between 8 and 9 years old, with 20 students in parallel A and 22 in parallel B. Permissions were obtained to carry out the research within this educational setting.

4 Results and Discussion

In order to contrast and then be able to make a balance between the experimental group and the control group, the results obtained from the questionnaire applied to this group that belongs to the Fourth EGB B of the U.E. Oswaldo Guayasamín is shown.

According to the table showing the result of the test that measures the children's ability to perform logical mathematical and linguistic reasoning, making inductive deductions, reasonably relates the data of the sets and solves coherently. The level of complexity increases as the test progresses, so the level of reasoning goes from low to higher.

Children aged 8 to 11 years should answer only the first 8 questions, older children should answer all of them [6] (Tables 1 and 2).

Table 1. Population/sample

Observation units	No	%
Parallel A (Control)	20	49,35
Parallel B (Experimental)	22	50,64
Total	**77**	**100%**

Based on the table and considering the answers of the 3 categories measured (operative thinking, space-time and figure background), the following results have been obtained. Of the 16 questions that were applied to the experimental group and verifying the range of their age, their assertiveness in the answers was an average of 4.5, which corresponds to an average logical reasoning and with this indicative, work should be done to improve their reasoning; the data is confirmed with the following table of results.

Table 2. Results of operative thinking in the control group

Number of items	Number of students	Number of responses	Number of hits	Percentage
5	20	100	54	54%
Spatiotemporal result				
Number of items	**Number of students**	**Number of responses**	**Number of hits**	**Percentage**
6	20	120	45	37%
Result figure background				
Number of items	**Number of students**	**Number of responses**	**Number of hits**	**Percentage**
5	20	100	38	38%

Table 3. Levels of reasoning.

Number of hits	Level
0 to 3 hits	Low logical reasoning
4 to 6 hits	Average logical reasoning
7 to 8 hits	High logical reasoning

Table 4. Projects proposed for the implementation of the research.

PROJECT 1	Starting the game, recognizing lego blocks and figures, pattems and sums. Elements of logical thinking to be developed Activity 1 - Starting the game Activity 2 - Calculation of areas and perimeters Activity 3 - Addition patterns
https://view.genial.ly/6238902bfc54140011d5572b/presentation-lego-con-wedo-20-parte-1	
PROJECT 2	Awaken your senses - Operational thinking Notion of multiplication and patterns Activity 1 - WEDO 2.0 Installation Activity 2 - first steps with WEDO 2.0 Activity 3 - Cooling fan
https://view.genial.ly/6238959816d4b40012357c09/presentation-lego-wedo-20-parte-2	
PROJECT 3	Create and invent - Temporal space Notion of multiplication speed distance Activity 1 - Build a race car
https://view.genial.ly/62389c8db0c9260018cf47d9/presentation-lego-wedo-20-parte-3	

4.1 Implementation of the Proposal

The children develop their skills at an early age and it is necessary that the skills and abilities of mathematical logic be reinforced as soon as possible, the project proposal is feasible because the infrastructure, the implements, the predisposition of the authorities, teachers and children are available to implement the proposed project; additionally, the children are computer natives and they will love working with technology.

The project's feasibility is underpinned by various factors. Socio-cultural aspects emphasize the significance of inclusive education and values in fostering students' logical skills, preparing them for academic challenges and lifelong success. Environmentally, the project's use of reusable materials, particularly LEGOS, aligns with eco-friendly principles, reducing waste and pollution. Financially, the researchers are committed to fully financing the project, ensuring its economic viability. Administratively, the proposal has garnered approval and sparked anticipation among authorities, highlighting strong administrative support for its analysis, development, and implementation. In terms of technical aspects, the project benefits from the researchers' expertise in computer science and programming, ensuring the application of the latest technical knowledge. Project phases are designed to last approximately three to five academic hours, with flexibility for adjustments based on students' needs and available time. Each project has an approximate duration of three to five academic hours. The phases have the same importance for the follow-up of the project, but you can modify the time spent in each phase depending on the needs of the student and the time available to him/her (Fig. 2).

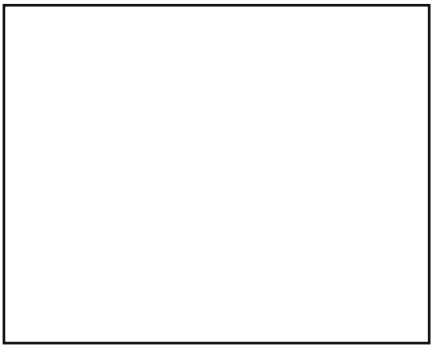

Fig. 2. Implementation of the teaching strategy with Lego Education

4.2 Current Situation

To determine the impact of the applied proposal, the questionnaire had to be sent again to the two experimental and control groups. These data are reflected in Tables 3 and 4, which show the level of progress of the experimental group versus the control group (Tables 5 and 6).

Table 5. Results of operational thinking Experimental group current situation

Number of items	Number of students	Number of responses	Number of hits	Percentage
5	22	110	72	65%
		Spatiotemporal result		
Number of items	**Number of students**	**Number of responses**	**Number of hits**	**Percentage**
6	22	132	81	61%
		Result figure background		
Number of items	**Number of students**	**Number of responses**	**Number of hits**	**Percentage**
5	22	110	62	56%

Table 6. Results of operative thinking group Control current situation

Number of items	Number of students	Number of responses	Number of hits	Percentage
5	20	100	53	53%
		Spatiotemporal result		
Number of items	**Number of students**	**Number of responses**	**Number of hits**	**Percentage**
6	20	120	47	39%
		Result figure background		
Number of items	**Number of students**	**Number of responses**	**Number of hits**	**Percentage**
5	20	100	35	35%

4.3 Synthesis of Results

After collecting data from the experimental and control groups, we obtained results that were detailed in Tables 3 and 4, which reflect the level of reasoning, being 4.4 for the fourth grade EGB A (experimental group) and 4.3 for the fourth grade EGB B (control group); in summary, the two grades are located in the medium logical reasoning range detailed in the following graph (Fig. 3).

Once the proposal was executed with the experimental group in the established period and having completed the projects, the questionnaire was applied again to verify whether the proposal met the objectives set; the results were as follows: Experimental group had an average percentage of 6.66 points, which would be between the medium and high level, considering that at the beginning of the proposal it was between the low

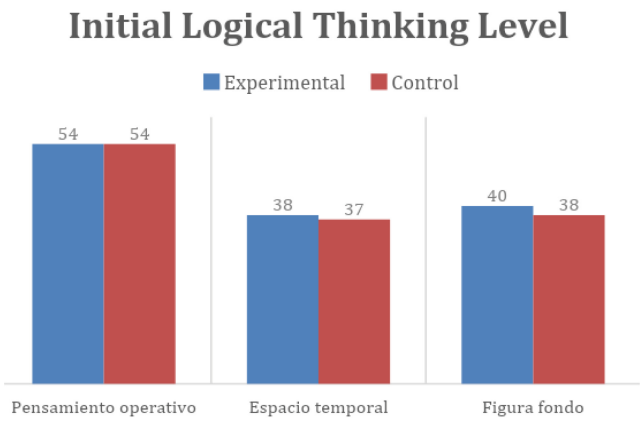

Fig. 3. Level of Logical Thinking Initial Situation

and medium level, that is, if an increase in mathematical logic skills has been achieved. In contrast with the control group that remains between the low and medium level, as shown in the graph (Fig. 4).

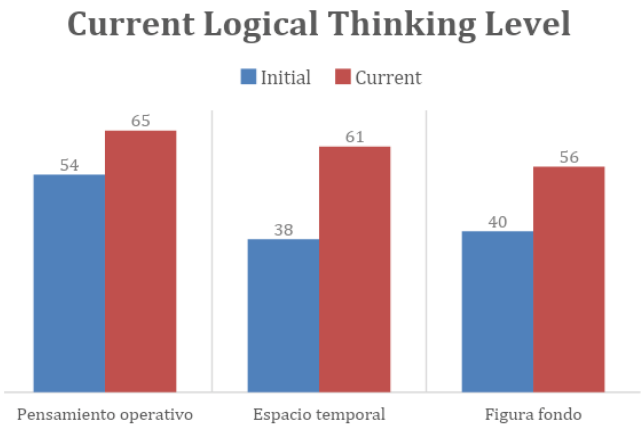

Fig. 4. Level of Logical Thinking Current Situation

As can be seen in the graph, the increase in the average to 6.0, which corresponds to an improvement of 22%, is due to the fact that the activities carried out in the proposal were of interest to the students, sparking creativity, a sense of inquiry, and collaborative work. Currently, technology significantly contributes to student teaching and learning. In contrast, the control group, who followed regular classes, has an average of 4.2, confirming that traditional classes are not engaging and lose the students' interest.

The initial assessment revealed no significant differences in logical thinking between the experimental group and the control group, indicating that both groups had a similar starting point in this regard. However, the critical aspect lies in the significant impact

of the strategy that included Wedo 2.0 and Lego Education on the experimental group. After the implementation of this strategy, the experimental group experienced a considerable advancement in their levels of reasoning. They reached a medium-high level of logical reasoning, reflecting significant progress in their logical-mathematical skills. In contrast, the control group, following traditional teaching methods, maintained their logical reasoning at a level ranging between low and medium. These nearly unchanged results underscore the limitations of conventional methodologies in nurturing students' logical thinking.

These findings reinforce the hypothesis that the implemented strategy, which combined technological tools and encouraged creativity, teamwork, and research, played an essential role in the significant improvement of the logical reasoning skills of the experimental group. This contrast between the experimental group and the control group highlights the importance of adopting innovative and effective pedagogical approaches to enhance students' cognitive skills and academic performance. Additionally, these results provide valuable insights into how educational practices can influence the development of key skills in the school environment.

5 Conclusions

This study highlights that the implementation of technological tools in mathematics education has significant potential to enhance students' logical and mathematical capabilities. Through the use of innovative resources like Legos and block-based programming, an increase in creativity, research skills, willingness to collaborate, and self-learning autonomy was observed. This empowers students in their educational journey and lays a strong foundation for the development of their logical thinking, enabling them to make informed decisions based on real-world situations.

However, it is essential to acknowledge that this study has certain limitations, such as the relatively small sample size and a focus on short-term outcomes. These limitations could constrain the ability to generalize the findings to a broader population and underscore the need for long-term research to fully comprehend the sustainable effects of these innovative educational methodologies. Ultimately, the incorporation of technological tools in mathematics education emerges as a viable strategy to strengthen students' logical and mathematical skills and foster their engagement and interest in the educational process, aligning with the demands of an ever-evolving society.

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Mapping Women STEM Initiatives in Latin American Countries: Bolivia, Brazil and Peru

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Abstract. The main objective of this article is to show a systematic literature review to map studies dealing with initiatives that aim to promote the insertion and permanence of women in Technology and Engineering (TE) careers, in Bolivia, Brazil and Peru. This is the first step to contribute to the generation and use of cross-country comparable open data to assess policies and interventions to reduce the gender gap in Science Technology Engineering and Math (STEM). The findings show limitations in the literature review of publications in English on initiatives to address female representation and leadership in the STEM field in these countries.

Keywords: Women in STEM · Latin America · Gender Gap · Women in STEM · Gender Equality

1 Introduction

The scant presence of women in technology is a fact discussed by researchers around the world. According to Mexican researcher Patricia G. Guevara, this relative absence is linked to "a long path of patriarchal, cultural, political and economic mechanisms and a gender ideology impregnated with images, myths and metaphors that have characterized scientific thought as objective and masculine mediating its historical exclusion" [9]. Not coincidentally, the fifth global goal established by the United Nations in 2015, which concerns gender equality, focuses on "Achieving gender equality through empowering women and girls". In line with this goal, there has been in Latin America, especially in the last ten years, a growing number of initiatives aimed at promoting the insertion of girls and women in technologies [13]. Given this scenario, it is worth asking what would be the best ways to access information about these initiatives.

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So, the present research aims to conduct a systematic literature review to map studies dealing with initiatives that aim to promote the insertion and permanence of women in Technology and Engineering (TE) careers. The focus was on the academic production of three countries: Bolivia, Brazil and Peru. It is worth pointing out that, in this work, we start from the idea that initiatives include actions, activities, events and/or programs that were documented. With regard, specifically, to the initiatives - the target of the research at hand -, three different sources were used to find them: academic literature, social networks (Instagram, LinkedIn, and Facebook), and gray literature. What will be presented concerns the data found in the literature review.

This article is organized into the following sections: works related to the theme of this research, the method used to conduct the literature review, the results found, and finally, the final considerations.

2 Related Works

Since in the last decade the number of Latin American initiatives, to promote gender equality in TE careers, has grown [13], some research has been conducted to map them. The work of Ruiz, Fernandez and Carvajal [24] presents the results of a bibliographic search of initiatives that have been carried out in countries of Latin America, to reduce the gender gap in information technology (IT). Twenty-three initiatives were identified in 18 countries: Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Dominican Republic, El Salvador, Ecuador, Guatemala, Guyana, Honduras, Jamaica, Mexico, Nicaragua, Panama, Peru, and Uruguay. Each country describes only one initiative, except for Brazil and Uruguay, with two initiatives each.

Concerning the countries of Bolivia, Brazil, and Peru, which are the focus of this paper, the Bolivian initiative identified by the bibliographic search conducted by Ruiz, Fernandez and Carvajal [24] was the Club STEAM[1], a private initiative created by Energea - Tecnonautas with support of the Panamerican Development Foundation and Boeing. The two Brazilian initiatives were: (a) Programa Meninas Digitais[2] (Digital Girls Program, in English), a non-profit initiative (program) idealized and conducted by the Brazilian Computing Society (SBC) since 2011, and; (b) GSMA Tech4Girls[3], a private initiative (event/workshop) held in Brasília in 2019 with the support of Global System for Mobile Communications Association (GSMA), a global organization representing the mobile ecosystem. Finally, the Peruvian initiative mapped was the Student Role Model Program, a public initiative (program) proposed by the Professional School of Software Engineering of the National University of San Agustin of Arequipa [28].

Although only two Brazilian initiatives are mentioned in Ruiz, Fernandez and Carvajal [24], other works explore the scenario in Brazil deeply, bringing an increasing number of initiatives. A systematic literature review [14, 15] looked for educational initiatives to retain women in Brazilian universities in Computing majors between 2010 and 2019.

[1] Available in: https://tecnonautasbolivia.com/club-steam/.

[2] Available in: https://meninas.sbc.org.br/.

[3] Available in: https://www.gsma.com/latinamerica/gsma-tech4girls-arrives-in-brazil-to-encourage-girls-into-stem-careers/.

The following databases were explored: Google Scholar, Scopus, Web of Science, Proceedings of LAWCC[4] - Congress of Latin American Women in Computing and WIT[5] - Women in Information Technology. The results reveal that LAWCC and WIT are the two main initiatives (events/conferences) where the Brazilian initiatives (actions, activities, events) are more frequently published, with 15 and 39 papers, respectively. Concerning the Brazilian initiatives, the authors emphasize that the Digital Girls Program has around 100 sister projects. The systematic literature review conducted by Holanda et al. [14, 15] identified and described some of the characteristics of 28 educational initiatives, most of them Digital Girls Program's sister projects.

Additionally, Santana and Braga [26] conducted research to map Brazilian research, focusing on gender in the computing field. Through a scientometric analysis, the authors analyzed the papers published in the CSBC (SBC Conference) events (base and satellite) in three years: 2017, 2018 and 2019. The results reinforce that WIT has the greatest number of women as authors, among all the events in the CSBC, reinforcing the importance of this initiative to promote an academic space which increases the works related to STEM with women's authorship. Finally, Maximino et al. [19] analyzed the papers published in WIT from 2016 and 2021 trying to identify the main themes discussed in this event. The results complemented the outcomes of previous works published in WIT: Cesario et al. [5] which identified the projects described in the papers, and Bordin et al. [4] which investigated different characteristics of authorship.

As mentioned above, according to Holanda et al. [14, 15] the two main academic conferences that discuss the presence of women in STEM in the Latin America context are the LAWCC organized by CLEI - Centro Latinoamericano de Estudios en Informática and the WIT organized by SBC. Both events are held annually, LAWCC since 2009 and WIT since 2007, however the call for papers began only in 2016 for WIT.

Most of the papers published at these conferences are related to research, experiences and initiatives in a specific country. For example, the papers published in WIT are mainly about Brazilian studies. On the other hand, in the LAWCC's proceedings, we can find works about the theme of women in STEM in Argentina [23], Bolivia [25], Brazil [2, 26], Chile [29], Costa Rica [1], Ecuador [6], Panama [21, 26], Paraguay [32], Uruguay [8], among others.

Therefore, it is evident that previous works using systematic literature review to identify initiatives which aim to reduce the gender gap in STEM, bringing results from more than one country in Latin America, are rare. To investigate the scenario in Bolivia and Peru and to complement the data from Brazil, the research described in this paper was conducted. This research comprises one of the stages of the project Latin American Open Data for Gender Equality Policies Focusing on Leadership in STEM funded by the International Development Research Centre (ProjectID #109798)[6], which aims to provide policy and leadership data regarding the presence of women in STEM in Latin America, executed in Brazil, Bolivia and Peru. This point justifies the scope that interests us in these three countries. The methodology chosen is presented in the next section.

[4] Available in: https://clei.org/lawcc/.

[5] Available in: https://sol.sbc.org.br/index.php/wit.

[6] https://ellas.ufmt.br/.

3 Methodology

To map the existence of initiatives that promote gender research in TE, this research used three strategies: (i) Systematic Literature Review (SLR); (ii) Social Networks and (iii) Grey Literature. This article focuses only on the Systematic Literature Review descriptions and results.

3.1 Systematic Literature Review

To map the initiatives that aim to promote the insertion and retention of women in STEM careers, a Systematic Literature Review (SLR) was carried out, using the Parsifal[7] online tool to support and document this process. In the initial planning phase, the research objectives, PICOC, research questions, search string, keywords and synonyms, source selection and inclusion and exclusion criteria were developed.

The PICOC protocol is used to assist in structuring the question to be answered by the research and according to Wohlin et al. [31], the acronym PICOC means population, intervention, comparison, outcome and context, being: **Population**: a group of people, programs or companies from which evidence is collected; **Intervention**: intervention applied in the empirical study (technology, tool or procedure under study); **Comparison**: the comparison to which the intervention is compared, that is, how is the control treatment defined?; **Outcome**: statistical and significant results of the experiment; and **Context**: expanded view of the population, including whether it is carried out in academia or industry, in which industry segment, and also the incentives for the disciplines.

From PICOC, Parsifal generated the keywords and the search string. The research questions used in the protocol of PICOC were: 1. What are the Bolivian/Brazilian/Peruvian initiatives to promote a greater representation of women in STEM? 2. What is the focus of these actions? 3. What is the target audience for the initiatives? 4. What are the actions of these initiatives? 5. What is the scope of the initiatives? e.g.: local, regional, and national. 6. What is the format of these actions? e.g. online, face-to-face, hybrid. 7. How do the initiatives get funded?

The string obtained with the application of the PICOC protocol was used in the search bases selected for the SLR.

Search string: **(“girl? in computer science” OR “girl? in engineering” OR “girl? in information technology” OR “wom?n in computer science” OR “wom?n in engineering” OR “wom?n in information technology”) AND (“Bolivia?” OR “Brazil?” OR “Digital” OR “Peru?” OR “STEM” OR “education?” OR “leadership”) AND (“activit?” OR “initiative?” OR “program?” OR “project?”).**

Considering the results previously presented in Sect. 2 (Related Works), from studies carried out in Portuguese and Spanish, that is, in the context of Latin America, and the universalization of knowledge in the English language, this language was chosen for this study, according to the descriptors presented above in string.

In the driving phase, BibTeX files from the Association for Computing Machinery (ACM), IEEE Xplore, Web of Science and Scopus databases were imported. Then, duplicate articles were identified among all sources and the selected studies underwent

[7] Available in: https://parsif.al/.

a quality assessment performed by two reviewers who inspected the title and abstract from the inclusion and exclusion criteria, to classify them as "accepted" or "rejected" to the SLR.

Reviewer 1: master's student with academic experience in SLR.

Reviewer 2: graduated with a Bachelor of Information with academic experience in SLR.

The inclusion and exclusion criteria are described as follows:

Inclusion Criteria: 1) Years between 2017 and 2022 and initiative carried out in Bolivia, an initiative carried out in Brazil, an initiative carried out in Peru; 2) Be an initiative that encourages the insertion of women/girls in STEM areas; and 3) Be an initiative that encourages the leadership of women (in general).

It is important to highlight that programs, projects, community, lectures, conferences, courses and training that bring women/girls closer to STEM areas were considered as initiatives to insert women/girls in STEM areas. In addition, initiatives that promote awareness and engagement of women in leadership, both academically and in the labor market, were also considered.

Exclusion Criteria: 1) Actions carried out outside the territorial scope; 2) Not being from the STEM area; 3) Not being specific to women; and 4) Research that is not an initiative.

We also highlight that among the exclusion criteria, we have research that is not initiatives, such as SLR not focused on initiatives, gender research, a gap of professionals in the exact area and comparison of positions and salaries by gender.

In Fig. 1, we have a schematic of the SLR stages adopted to carry out the works, which include the identification of primary articles in the bases selected for this research, and the selection of articles initially accepted after review title and abstract.

Following the steps of the SLR, we started the work with 775 primary articles, after the initial review by title and abstract, we selected 11 articles to be read in full for the final selection of articles.

4 Results

Eleven articles were analyzed, the majority (64%) of which were published in 2020, as shown in Table 1. The increase in the number of publications in 2020 may be related to some of the reasons: (i) the pandemic period, where projects stopped face-to-face actions and used this time to document them in scientific articles; (ii) changes in basic educational guidelines, which stimulated discussions on the subject, leading to greater concern in the scientific community. All articles had Brazil as their object of study and only one included a second country, Spain.

Two articles describe the survey's results, Paganini and Gama [21] focus on hackathons and García-Holgado et al. [10] analyze the gender and cultural perceptions of support in engineering studies.

Two articles present an SLR [14, 15] are quite similar but the first one comprehends the period from 2010 to 2019 and the second one from 2010 to 2020. Most articles describe initiatives to reduce female inequality in STEM involving programs, projects with schools, and card games [7, 12, 16, 18, 20, 27, 30] (See Table 1).

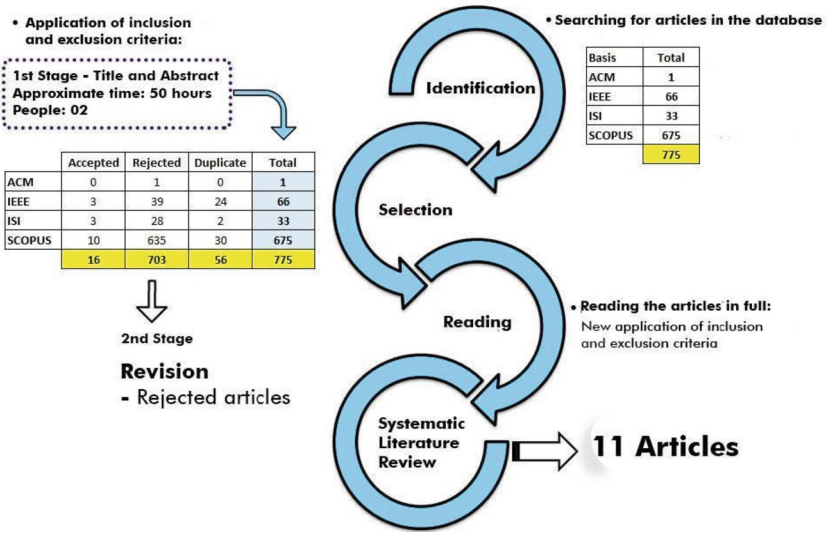

Fig. 1. Systematic Literature Review (SLR) Source: Own authorship.

Table 1.Papers analysis. Source: Own authorship.

Authorship	Focus	Audience	Actions	Scope	Format	Funded	Countries analysed in the study
[MOREIRA et al., 2020]	Initiatives	Public high schools	Workshops, technical trainning, labs visit	Regional	Face-to-face	CNPq, MCTIC, Petrobras, PROBEX	Brazil
[HOLANDA et al., 2020]	Initiatives (SLR)	University	Workshop, Competitions, Keynote	National	Face-to-face, online and hybrid	FAPDF, CNPq, MCTIC	Brazil
[GARCÍA-HOLGADO et al., 2020]	Survey	University	Student profiles and factors of influence in career choices	International	online	Erasmus	Brazil and Spain
[MACIEL et al, 2018]	Initiatives	All levels from elementary school	Unplugged computing, card games, app and game development, programming classes, competitions, lectures, workshops, etc	National	Face-to-face, online and hybrid	Not specified	Brazil
[DE AGUIAR GOMES et al., 2018]	Initiatives	Elementary and High School	Lectures, events, dynamics, trainning in computational apllications	Regional	Face-to-face	Not specified	Brazil
[PAGANINI and GAMA, 2020]	Survey	Hackathon participants (age is not specified)	Hackathon	Local	Face-to-face	Not specified	Brazil
[WILLIAMS, 2020]	Mentoring	University	Talks, technical visits, teacher workshop	Local	Face-to-face	Not specified	Brazil
[SAUER et al., 2020]	Initiatives	Elementary and High Schools	Teacher training courses in STEM, workshops, competitions training, fairs, science and astronomy club	Regional	Face-to-face, online and hybrid	Not specified	Brazil
[GUIMARÃES et al., 2020]	Card game addressed aspects of Women in STEAM	Chidren from 6 years old	Play in fairs and events	Regional	Face-to-face	CNPq, CAPES, FAPEAM	Brazil
[HOLANDA et al., 2021]	Computational activities (SLR)	Elementary schools	Unplugged computing, card games, app and game development, programming classes, competitions, lectures and workshops	National	Face-to-face, online and hybrid	Not specified	Brazil
[LOPES and ODAKURA, 2021]	Website	Elementary schools	Learning objects about gender equity	National	online	Not specified	Brazil

Final Considerations

Data guides us on many decisions. With them, new paths for research and scientific and technological development can be planned. Also, on formulating public and private policies for a better society. In this line, there is an emerging problem: the women's gap in leadership positions in the STEM area.

The study presented in this article brings data, systematically collected, as part of the project's research. In general, the mapping of initiatives allowed us to identify a few initiatives, the majority of them were found in Brazil while very few were identified in Peru and Bolivia.

The Systematic Literature Review presented the search string and the language as limitations. Several tests were necessary to adjust this string, which initially brought many articles, but which had no direct relationship with the research topic and left articles known to the team out of the results of these searches. Another difficulty was the issue of language because initially it was considered the creation of a Parsifal for each country, but the searches for articles in Portuguese showed little or no results, depending on the publisher format of each research base. To resolve these issues, a Parsifal was chosen for Brazil, Bolivia and Peru and a search string that brought the results of these countries in English.

The low number of initiatives mapped by the Systematic Literature Review reveals that most of the initiatives do not publicize their aims, actions and results in academic production, mainly in English. In a way, not publishing research in English ends up limiting its dissemination throughout the world. By the way, comparing the results with the papers published in LAWCC and WIT, which are mainly written in Portuguese or Spanish, it is evident that it is necessary to conduct decolonial research [17]. It means that the Parsifal tool must be able to search in national databases such as SBC OpenLib[8] - Digital Open Library of the Brazilian Computing Society. On the other hand, national databases must have ways to provide a search with the same string used in international databases such as ACM and IEEE, for example.

Additionally, the growth of initiatives to increase the number of women in STEM is well known. Consequently, if their results are not being published in academic production, they are probably using other communication channels to reach their target audience. This indicates that new methods are needed to search for this kind of data, for example, methods to map social media [22], gray literature [3], or other methods that slow us to have access to different information, in a hybrid way [11].

In the future, new research can be developed deepening the results from this mapping and crossing this data with others, in the context of a main project. Placing those data as open, for web searches, society can benefit from the development of new applications and policies that benefit everyone. And, with the support of strategies like this, we can have more women at leadership points in STEM careers.

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[8] Available in: https://sol.sbc.org.br/index.php/indice.

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Gender Equality Policies in STEM in Latin America - A Systematic Literature Review

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Abstract. As the imperative for equitable representation in leadership roles within STEM grows more pronounced, the meticulous examination of existing policies that promote gender equality becomes increasingly vital. This scrutiny not only paves the way for progress but also fosters a culture of social inclusion. This research provides a snapshot of one facet of an ongoing, comprehensive research initiative dedicated to advancing impactful research on women's leadership within STEM domains across low- and middle-income countries (LMICs). Specifically, this study undertakes the crucial task of identifying gender equality policies in the dynamic landscape of Latin America and the associated literature corpus. To achieve this, we conducted a systematic literature review, employing four reputable citation databases as our primary resources. The findings of our inquiry illuminate the multifaceted challenges associated with acquiring cross-country comparable data—essential for the assessment of policies and interventions designed to mitigate the pervasive gender gap in STEM. This study contributes by identifying the academic discourse on the topic and offering data for policymakers and researchers interested in improving women's participation in STEM and promoting enduring gender equality.

Keywords: Gender equality · STEM · Latin America · Systematic Literature Review

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1 Introduction

Gender equality, as underscored by the United Nations [1], stands as a fundamental pillar for cultivating a world characterized by peace, prosperity, and sustainability. Despite notable strides in the last decade towards increasing women's participation in Science, Technology, Engineering, and Mathematics (STEM), a significant gender gap still endures [2,3]. This imbalance is most strikingly evident in leadership positions within these fields. Globally, a mere 24% of leadership roles in the technology industry are occupied by women [4]. While this represents an improvement, it remains a distressingly low figure. The chasm in STEM and leadership roles is not confined to advanced economies; it extends to countries in Latin America as well [5]. On average, women's hourly wages amount to just 83% of their male counterparts' earnings [6]. Moreover, in the public sector, women hold a meager 20% of senior management positions and constitute less than 10% of corporate board memberships [7].

Governments and organizations have recognized the urgency of promoting gender equality and have devised various policies and programs to address this issue [8,9]. Latin American nations are no exception, with each country in the region implementing its own gender equality policies [10,11]. However, acquiring a comprehensive and systematic understanding of these policies proves challenging. In their study, Blofield and Hoffmann [11] found that socioeconomic disparities can shape the outcomes of gender equality policies in Latin America. Given the diversity of gender equality policies across the region, it becomes imperative to embark on a systematic examination of these initiatives.

Such studies addressing gender disparities hold significant relevance, as they pave the way for fostering social inclusivity [12]. They also provide invaluable insights for both academics and practitioners striving to instigate essential changes aimed at enhancing diversity, equity, and inclusion (DEI).

In light of these considerations, this study scrutinizes existing gender equality policies affecting STEM disciplines in Latin America, with a special focus on three nations: Bolivia, Brazil, and Peru. To this end, a Systematic Literature Review (SLR) [13] was carried out. This paper offers an overview of one of the research components within a broader ongoing project, in executing in this countries [anonymized for submission], aimed at advancing gender analysis and promoting women's leadership in STEM fields within low- and middle-income countries (LMICs). The overarching goal is to champion gender diversity and inclusion as catalysts for transformative and high-impact research.

The results presented in this study are part of the efforts of the international research network "Equality in Leadership for Latin America STEM" (ELLAS)[1], established in 2022. This network involves seven Latin American universities and one North American partner that run the project called "Latin American Open Data for Gender Equality Policies Focusing on Leadership in STEM" [14]. Its goal is to generate and promote a cross-country comparable open data platform

[1] https://ellas.ufmt.br.

to assess policies and interventions aimed at addressing STEM gender disparity in three Latin American countries, Bolivia, Brazil, and Peru [15].

The structure of this paper unfolds as follows. In the subsequent section, we present the methodology employed for the Systematic Literature Review we conducted. Section 3 brings the description of the selected works. Section 4 delves into our findings, and finally, we draw our conclusions.

2 Information Search Methodology

We conducted a Systematic Literature Review (SLR) to identify the existing gender equality policies that influence the career development of women in STEM in Latin America. In a SLR, the search for documents focuses on abstracting services or databases that provide access to articles about the topic of interest, according to Kitchenham *et al.* [13]. The SLR process proposed by those authors contemplates three steps and was the chosen method to execute the second phase of the literature review. The first step is planning, where research questions are identified, and the review protocol is drafted. In the second step, there is the selection of studies, which is guided by the protocol elaborated in the first step. Finally, the third step analyzes the results and points out where they were reported.

The systematic literature review approach was especially relevant, considering that each research study found was unique, in that it could focus on a specific context (project, university, community, etc.), follow a specific methodology, and use different levels of analysis. Besides, each context may present different meanings for the collected data based on the academic area, culture, and techniques used to gather the data. Our SLR questions were:

Q1 What types of gender policies exist in Latin America about women in STEM?
Q2 What types of gender policies have been implemented about women in STEM in Bolivia, Brazil and Peru?
Q3 How are policies promoting women's participation in STEM fields in Latin American?

In the planning step of the SLR, we applied the PICOC (Population, Intervention, Comparison, Outcome, and Context) methodology, proposed by Petticrew and Roberts [16], to select the terms that could help the definition of the search string. In our scenario, we foresaw the following components: "Gender, Women", for Population, "Inclusion, Permanence", for Intervention, "Enablers,

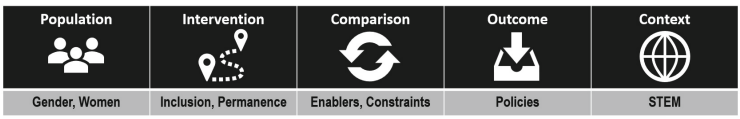

Fig. 1. Terms selected for the search string using PICOC

Constraints", for Comparison, "Policies", for Outcome, and "STEM", for Context, as shown in Fig. 1.

The biggest challenge in conducting this process was the construction of strings, which needed to be adjusted depending on the database. In this way, we formulated a pilot string based on the PICOC terms, and we applied the search in four databases: ACM Digital Library, IEEE Digital Library, ISI Web of Science, and Scopus. Those were the tested search string:

S1: ("policies" OR "policy") AND ("gender" OR "women" OR ("gender" AND "diversity")) AND "STEM"

The string S1 was included in the preliminary selection, which returned 285 studies. However, it showed us that most of these studies were from initiatives in countries outside Latin America. We also identified that it would be necessary to include keywords similar to the terms used, for example: policy - policies, could also be norms, regulations, laws. Thus, we elaborated a second search string:

S2: ("policies" OR "policy") AND ("gender" OR "women" OR ("gender" AND "diversity")) AND "STEM" AND ("Peru" OR "Bolivia" OR "Brazil" OR "Brasil")

The string S2 returned only five articles, making a deeper study on the proposed question unfeasible. After these preliminary searches and considering the keywords identified in the papers, we redefined the PICOC terms and elaborated a final search string, presented as follows: "Women, Female", for Population, "Equity, Equality, Diversity", for Intervention, "Gender discrimination, Gender wage gap", for Comparison, "Policies, Norms, Regulations, Laws", for Outcome, and "STEM, Technology, Engineering, Mathematics, Latin American, Peru, Bolivia, Brazil", for Context, as shown in Fig. 2.

Population	Intervention	Comparison	Outcome	Context
Women, Female	Equity, Equality, Diversity	Gender discrimination, Gender wage gap	Policies, Norms, Regulations, Laws	STEM, Technology, Engineering, Mathematics, Latin American, Peru, Bolivia, Brazil

Fig. 2. Revised terms for the search string using PICOC

To obtain a larger sample we decided to go beyond the studied countries — Brazil, Peru and Bolivia —, including other Latin American countries in our search. As such, the final search string was:

S3: (”policies” OR ”policy” OR “regulations” OR “laws” OR “norms”) AND (”gender” OR ”women” OR ”Female” OR ”diversity” OR “equity” OR “equality”) AND (”STEM” OR “engineering” OR ”science” OR “technology” OR ”mathematics” OR ”information technology” OR “TIC” OR “ICT”) AND (”Peru” OR “Bolivia” OR “Brazil” OR “Brasil” OR ”Latin American” OR “Mexico” OR “Argentina” OR “Costa Rica” OR “Guatemala” OR “Colombia” OR “Chile” OR ”El Salvador”)

We used the Parsifal tool [17] to support us during the systematic review process. Our search results returned a total of 391 papers, which were imported to Parsifal to execute the study selection. Figure 3 represents all the steps of the selection of papers.

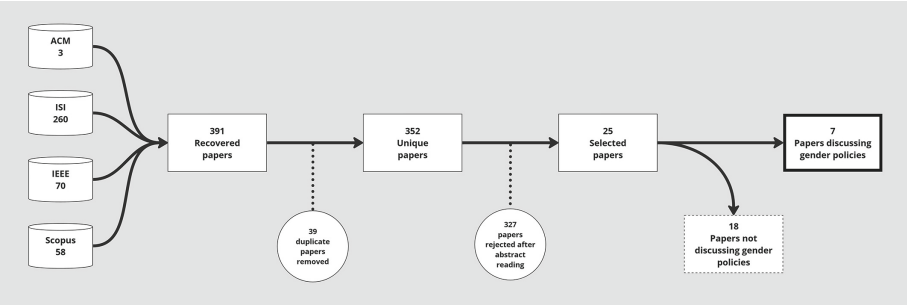

Fig. 3. Steps of the selection of papers during the systematic review process

Then, 39 duplicated papers were eliminated, and 327 papers were rejected after the abstract reading because of one or more exclusion criteria. Consequently, 25 papers published from 2018 to 2022 and focusing on 10 different Latin American countries: Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, El Salvador, Ecuador, Mexico and Peru, were selected for full reading, data extraction and analysis. After that, we concluded that, while 18 works dealt with practices, programs or processes related to gender equity, only 7 works were specifically discussing gender policies in fact. As such, for this initial study, we focused on analyzing these 7 studies, as presented in the next section.

3 Selected Works

In their examination of gender policies in Argentina, in [18] the authors pinpoint a specific type of policy instrument aimed at promoting women’s participation in science, technology, and innovation: prizes for women in science. Considering the L’Oréal-Unesco prize in Argentina, their approach delves into three key aspects, considering both research and policy formulation perspectives: the motivations

of the winners to participate, the effects they identify after being distinguished and their opinion about the participation of women in science and its relation to the objectives of the award. They concluded that prizes complement and do not replace other incentive instruments in the promotion of science, technology and innovation. The authors identified that, although the central effect identified by the winners themselves is the increased visibility they obtained, the prize lacks a dissemination effort on the role of women in science.

Shifting the focus to Brazil, one work focusing on gender policies was found. In [19], the authors set out to achieve three primary objectives in their study: (a) to understand the relationship that the company's diversity and inclusion policies have with the choice/permanence of employees in the company; (b) to assess how the workforce perceives the corporate environment in terms of diversity and inclusion; and (c) to compare whether the company's discourse and practice are aligned or not. They identified that these companies apply policies aimed at educating their employees. Such policies target inclusion and diversity, that is, they try to guarantee the hiring of employees from socially excluded social groups such as women, gays and lesbians and other minorities.

In the context of gender policies in Chile, in [20] the authors underscore the importance of integrating the gender perspective into the cybersecurity sector. Their work emphasizes that the National Cybersecurity Policy in Chile expresses the need of respect and promotion of human rights and, for such purpose, it is important to consider the gender approach. They propose that the Chilean State must identify, through periodic studies and surveys, the main risks, threats and shortcomings suffered by women in Chile in the face of the development and use of cyberspace. For such purposes, they must include the indicators for the development of the gender perspective in cybersecurity, identifying the origin of the shortage of women dedicated to cybersecurity in Chile. Moreover, the Chilean State and society in general should direct their efforts to encourage girls and adolescents to study careers related to cybersecurity.

Examining gender policies in Colombia, in [21] the authors report on a World Café conversation involving researchers and policymakers from higher education institutions. This conversation aimed to address the gender gap in STEM studies and has resulted in the proposal of principles, strategies, and actions for Latin-American partners. Forty-four people participated in the conversation to discuss about the potential actions, policies and strategies that might be developed in the universities to reduce the gender gap in STEM studies. The authors concluded that the conversations has been very significant to propose a draft of principles, strategies, and actions to be taken into account in the Latin-American partners' action plans to attract, make more accessible the access, retain, and guide women to the STEM disciplines and professional development.

One work focusing on gender policies in Costa Rica was found. In [22], the authors discuss the development of a set of national public policies towards reducing the gender gap in STEM fields. The methodology that was used followed the Triple Helix approach, which proposes that the solution of society's problems could be resolved by the execution of hybrid projects between universi-

ties, industry, and government. Five strategic axes were defined: (1) Attraction of women towards Science and Technology; (2) Training and permanence of women in Science and Technology careers; (3) Promoting scientific research employment opportunities in Science and Technology; (4) Appropriation of Science and Technology with a gender perspective; and (5) Sustainability and follow up of the policy. For each of the strategic axis, the following specific objectives and strategic actions were defined. The created policy was in public consultation when the paper was written, and the policies' impact should be evaluated later.

Turning our attention to Mexico, in [23] the authors investigate the operationalization of gender equity policies in a Mexican higher education institution. Their study focuses on the perspectives of male students and faculty regarding these policies and their impact on female students in Sciences and Engineering programs. In all, 3 students, 4 professors and 5 administrators were purposefully selected to participate in this study. The authors argue that focusing on the perspectives of men is crucial in gender issues, since transformation which does not involving men will likely be opposed by men in defense of gender privileges. Their findings reflect that male academics and students men were caught up in a conflicting position of accepting the policies in principle but rejecting them in practice. They conclude that gender equity policies and initiatives did not produce substantive change for female students and academics, instead they had very little positive material and practical consequences, and left female students and academics subjected to a gender unfriendly and insensitive learning environment.

In [24], another study on gender policies in Mexico, the authors scrutinize the effects of policies aimed at gender equity and women's empowerment. Specifically, the study interrogates gender representation in key management positions in state technological institutes (STIs) in Mexico's central zone. The authors analyzed employment and recruitment documents available on the national database and compared the statistics on gender lines to establish the percentage of male and female managers in the STIs. Despite the favorable gender policy framework, the results showed that a greater proportion of management positions were occupied by men who were underqualified academically and professionally. The authors conclude that gender difference may be used to explain the gender biased employment practices in key leadership positions in the STIs, and, as such, that there are still glaring gaps in terms of implementing policies in favour of women at the national level in Mexico.

4 Discussion

The seven studies selected were conducted in six different Latin American countries, including Argentina, Brazil, Chile, Colombia, Costa Rica and Mexico. Only for this last country we could find two studies, both mentioning that some gender equity policies have already been implemented, but are not effective.

The specific research objectives vary across the studies. For example, some studies examine the role of prizes for women in science (Argentina) or corporate

diversity and inclusion policies (Brazil), while others focus on policies related to cybersecurity (Chile) or higher education (Colombia and Costa Rica). However, as a whole we can affirm that all studies focus on how to close the gender gap in STEM either in education fields or in work opportunities.

All studies selected used empirical research methods, nevertheless, the exact methodologies and data collection techniques differed. Some studies involve surveys and interviews with various stakeholders, while others analyze employment and recruitment documents.

On addressing question Q1, we noticed that while the several studies addressed different types of gender policies, we could identify that they fall into eight categories, as synthesized in Fig. 4: Affirmative Action (hiring women, minorities from excluded social groups) [19], Attracting women's participation in STEM fields [19–22], Gender parity (for leadership/political positions) [24], Gender quota (ensure women's participation) [24], Identifying Women's Participation in STEM [20], Retention/empowerment during STEM training [21], Support Women's Career Growth [18,21,23], Zero tolerance for sexual harassment and violence at the workplace [20].

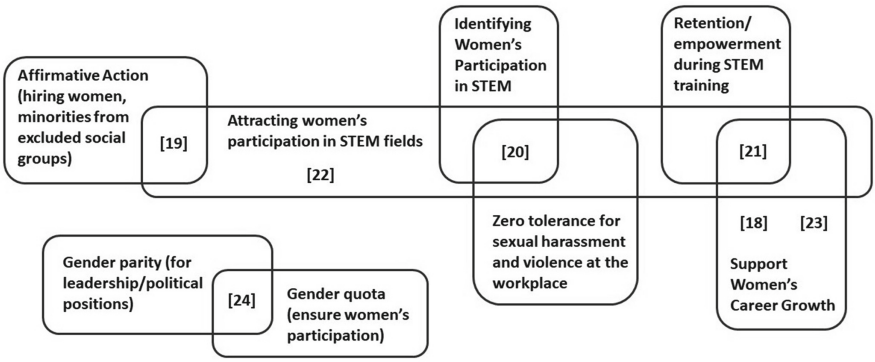

Fig. 4. Gender policy types addressed in each work

In summary, while these studies share common themes related to gender policies and equity, they vary in terms of geographic focus, policy types, research methods, research objectives, and specific findings. This diversity reflects the complexity and context-specific nature of gender policies and their impact in different Latin American countries. Regarding questions Q2 and Q3, we found that none of the selected studies provide information on policies put into practice or the evaluation of their results.

5 Conclusions, and Future Research Directions

Studies about gender equality policies are relevant because they help researcher and policymakers promote social inclusion. However, finding cross-country comparable data to assess policies and interventions to reduce the gender gap in

STEM has significant challenges related to language, access and structure of policies. Researchers and policy would benefit from open access data.

The main limitations of the systematic literature review are: i) we did the search only by using strings in English; ii) it includes only academic papers from journals and conference proceedings; iii) we analysed a subset of the works that were initially selected, while 18 other studies discussing practices, programs or processes related to gender equity ware put aside for later consideration.

As this is an ongoing work, these limitations can be overcome in the next steps of the research, respectively by i) performing extended searches with the strings written also in Portuguese and Spanish to recovering other local contributions of Latin American countries; ii) performing a gray literature search to complement the information gathered; and iii) including in the analysis all the 25 studies recovered in the literature search.

Ultimately, we believe that studies like this one may bring a relevant contribution by identifying the academic discourse on the topic and offering data for policymakers and researchers interested in improving women's participation in STEM and promoting enduring gender equality.

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Integrating Digital Narrative in Social Studies Teaching: Impact on Learning and Skills Development

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Abstract. Digital narrative has gained relevance in Social Studies teaching, allowing students to explore concepts in a more dynamic and participatory way. This research aims to integrate digital narrative into existing educational materials and curricula to support teachers in teaching Social Studies. A mixed qualitative and quantitative approach is used to evaluate the impact of digital narrative on student learning by collecting data through surveys before and after using digital narratives. The results indicate that digital narrative sparks interest, improves comprehension and retention of information, and strengthens critical thinking and analytical skills. Before the research, 61% of teachers did not use this strategy, but after its application, 97% consider that it generates dynamic and participatory learning in the inter-learning process.

Keywords: Digital Storytelling · Learning · Social Studies · Strategy

1 Introduction

The integration of Digital Narrative (DN) in Social Studies teaching is a fundamental part of the research on pedagogical innovations in the networked society, where education has experienced a surprising change towards the virtual environment, beginning a new era in the teaching and learning process. As pointed out [1], DN is presented as an innovative tool that transforms the way of teaching, by allowing the creation of interactive, open, reflective and dynamic content, in which students have the opportunity to continue learning according to their abilities and interests, while reinforcing their knowledge. In this context, DN shows a unique approach in education, being seen as a relevant and motivating activity that has a remarkable effect on students and their learning process. [2].

DN is an extremely powerful tool; when used appropriately by educators, it can contribute significantly to achieving quality education. This involves providing students with

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a comprehensive and excellent learning experience, boosting their motivation through innovative approaches that respect and adjust to their individual characteristics. In this context, teachers become guides and facilitators of new technologies to promote the development of digital skills and competences, both independently and in collaborative environments.

In the Organic Law of Intercultural Education [3], in article 6 paragraph j. "Guarantee digital literacy and the use of information and communication technologies in the educational process, and promote the link between teaching and productive or social activities", this highlights the emphasis on the incorporation of technology in the educational environment, recognizing the need to integrate education with the digital world and cultivate skills relevant to the current context, thus establishing an essential link between teaching and productive and social dynamics.

Likewise, the Code of children and adolescents [4] in article: 37, highlights the need for a comprehensive education that promotes the growth and potential of each individual in all spheres of their life. For this reason, DNs are an alternative to involve students in a playful way, stimulating their curiosity and nourishing their imagination, through the telling of stories on various topics that, at the same time, contribute to the preservation of traditions and cultures of the people.

Sustainable Development Goals (SDGs), point 4, [5], the UN Agenda 2030 seeks to guarantee quality education for all, that children achieve schooling according to their age and that educational institutions have the necessary resources to offer a quality educational service that takes advantage of technology in the field of education and innovation. In this context, "the boom of technologies in the educational scenario is not only providing support resources in teaching, but can also enable the reconfiguration of a dynamic, participatory, flexible and decentralized educational model" [6], It means, the innovation of technologies not only provides additional resources to support teaching, but also makes it possible to create a more interactive and dynamic educational approach.

The problem in the DN environment in Social Studies teaching focuses on the lack of digital skills among teachers and the underestimation of the importance of these skills in some cases. This results in students not being able to take full advantage of digital storytelling resources to build meaningful knowledge and develop relevant skills.

Thus, in order to address this problem, there is a need to prepare teachers in the management of DN, as strategies to "improve educational processes and promote meaningful learning." [7], This implies taking advantage of the benefits of DN in Social Studies teaching and ensuring quality learning for students. If teachers are not trained to guide students in this environment, there is a risk that an entire generation will lack the fundamental skills needed to succeed in today's society.

Consequently, Organization of Ibero-American States "mechanical tasks" can be carried out […] by computers and the techno-digital infrastructure that is accessible today [8], For this reason, it is essential to recognize creativity as a crucial skill and promote in students the development of their perception, their qualitative intelligence, their personal autonomy and their skills, taking advantage of the support offered by technology in the performance of mechanical tasks.

According to the Ministry of Education [9]. The use of technological tools has become broad connections in the sociocultural field and their use helps to understand

the different subjects, to improve and strengthen the learning processes, in which it is established that interaction in different areas contributes to improve and strengthen learning processes in the classroom. The United Nations considers that [10], that the educational narrative arises from a personal experience, which has an educational relationship with new digital trends. Hence the need to increase teaching didactics that facilitate the transfer of knowledge and establish learning strategies that allow better performance in the assimilation and retention of academic processes.

2 Related Work

Throughout the evolution of humanity, various means of communication have been used, from pictograms and smoke signals to the development of languages and dialects. Beginning with the third industrial revolution, also known as the technological revolution, which began in the mid-20th century, it was driven by the development of semiconductors and computer systems in the 1950s, which facilitated the creation of electronic devices that are commonplace today.

DNs are new ways of storytelling that appear thanks to the Internet and make use of free or freemium digital tools, used to explain a brand story in an innovative way. In the educational sector, digital narrative is a technique that seeks to attract the attention of the public through storytelling using social networks and ICT. This is a new form of digital narrative in the "line of innovation in educational fields, which implies rethinking didactic models and teaching and learning methodologies that are more active, dynamic and participatory" [11].

For Ochoa & Díaz [12], the evolution of DN worldwide in the educational field has generated multiple benefits for the development of communicative and creative skills that promote collaborative learning, personal expression and student participation in academic activities. That is, with technological advances in recent decades, users now have a more critical understanding; In the educational field, interactive narratives, innovative applications are being explored that offer new opportunities to get closer to reality using artificial intelligence, taking advantage of the benefits of the digital revolution in education to improve the learning process of Sciences Studies. A crucial factor is that the authorities of educational institutions must "assume the guidelines of the model to the point that they are reflected in teaching strategies adjusted to the different realities and practices" [13].

It is important to highlight that new multimedia narratives are acquiring increasing value and importance in current education. These tools make it possible to present information in an interactive and attractive way, which can enhance children's learning. In this sense, the question arises: What is the contribution of DN in teaching the subject of Social Studies? The objective of this research focuses on analyzing digital narrative as a strategy for learning Social Studies.

In this study, the potential of DN as an educational tool in Social Studies learning was analyzed. The poor use and lack of knowledge of teachers in this area was identified as the main problem. Its importance as a pedagogical approach and its effectiveness in student learning and motivation are justified. Several educational theories that support their integration in the classroom were analyzed, with the purpose of analyzing the

contribution of narratives in the learning of Social Studies, through a mixed study that compared the results before and after implementation.

Prior to the application of the DN in the teaching process, it was found that 61% do not use this strategy in the learning process, but already in the application phase, 97% consider that the use of interactive teaching strategies such as digital narrative, generate dynamic and participatory learning, achieving significant learning in students.

3 Methodology

The research is based on the mixed approach, considering that it allows us to carry out qualitative and quantitative analyzes of the object of study, allowing for a comprehensive understanding from the different factors of the educational context, which has contributed to achieving the objective of the research.

3.1 Participants

The population was 3,052 teachers from Educational District 17D05, of the Metropolitan District of Quito, province of Pichincha, in the country of Ecuador, from which the sample of 341 teachers was obtained, with experience in educational work, who contributed with information related to the research variables, through a survey applied online through Google Forms.

Of the 341 participating teachers, 76.83% correspond to the female gender and 23.17% to the male gender, 55.43% of teachers belong to the age range of 25 to 30 years, 19.94% in the age range from 31 to 40 years, 11.44% from 41 to 45 years, 9.68% from 46 to 50 years and 3.52% are over 50 years old.

3.2 Materials and Resources

In this study, the survey technique was used, consisting of 12 items, which was applied to the sample of teachers under study through Google Forms. Subsequently, the authors used the IBM SPSS statistical package to process the information collected and carry out the analysis and interpretation of the corresponding research variables (Table 1).

In order to achieve the objective of the study, the action research process was used, first applying a survey previously validated by experts in the research area, composed of 12 items, with response options using the Likert scale of seven points, related to the Digital Narrative and Social Studies variables, with the rating scale of 1: Strongly disagree, 2: Disagree, 3: Somewhat disagree, 3: Neither agree nor disagree, 4: Somewhat agree, 5: Agree, 6: Strongly agree.

After obtaining the results based on Lewin's model, two strategic axes were used: action and reflection, along with a second axis related to the organization. This analysis was carried out with a retrospective perspective and a prospective orientation, in the learning moments. Through this analysis and reflection, it was confirmed that the implementation of interactive teaching strategies, such as digital narrative, promotes a type of dynamic and participatory learning. Consequently, Digital Narrative models were developed based on the Skills with Performance Criteria of the Social Studies subject.

Table 1. Components and items of the questionnaire.

	Initial eigenvalues			Sums of charges squared of the extraction			Sums of charges squared of rotation		
	Total	% variance	% accumulated	Total	% variance	% accumulated	Total	% variance	% accumulated
1	6,45	53,7	53,7	6,45	53,7	53,7	3,73	31,1	31,1
2	1,94	16,2	69,9	1,94	16,2	69,9	3,02	25,2	56,3
3	0,66	5,50	75,5	0,66	5,50	75,5	1,21	10,13	66,4
4	0,54	4,49	80,0	0,54	4,49	80,0	1,09	9,11	75,5
5	0,46	3,90	83,9	0,46	3,99	83,9	0,99	8,31	83,9
6	0,44	3,67	87,5						
7	0,33	2,74	90,3						
8	0,28	2,39	92,7						
9	0,27	2,32	95,0						
10	0,23	1,98	97,0						
11	0,19	1,61	98,6						
12	0,16	1,34	100						

***Note*:** The items of the instruments used are presented according to the research variables

These models are designed to be replicated in educational institutions, which stimulates interest and interaction with students, thus generating meaningful learning experiences (Fig. 1).

Fig. 1. Teachers in training of Digital Narratives management

Likewise, teachers from the study area attended training sessions for the design and application of digital narratives in the subject of Social Studies, motivating them to use this tool frequently in the teaching-learning process. After the training process, the teachers applied digital tools in the teaching of Social Studies, for which an observation sheet was applied to verify the level of satisfaction of the students, showing that they awaken interest, creativity and stimulate learning.

4 Results and Discussion

The results of the research carried out on the sample of 341 teachers from Ecuador were obtained in the IBM – SPSS statistical program.

4.1 Reliability

The validity of the data collection instrument was verified by calculating Cronbach's Alpha, a coefficient ranging from 0 and 1. The closer the value is to 1, the higher the reliability of the instrument was considered. The items were completed using a seven-point Likert scale (Table 2).

Table 2. Cronbach's Alpha Reliability Statistics

Reliability Statistics		
Cronbach's alpha	Cronbach's alpha based on standardized items	No. of items (global questionnaire)
,879	,920	12

Note. Taken from IBM SPSS statistical software, reliability of teacher survey

The validity of the data collection tool was evaluated using Cronbach's Alpha, a coefficient that varies between 0 and 1. It is considered that the closer the value is to 1, the greater the reliability of the instrument applied. The results showed a coefficient of 0.879 and, based on the standardized items, 0.920. This indicates high reliability of the instrument used, which validates the frequencies under study (Table 3).

Table 3. KMO and Bartlett test

Kaiser-Meyer-Olkin measure of sampling adequacy		**0,917**
Bartlett's test of sphericity	Approx. Chi squared	2886,351
	Gl	66
	Sig	<,001

Note. Taken from IBM SPSS statistical software, reliability of the instrument

When using Kaiser-Meyer-Olkin, it is dissented that it is above the accepted limit of 0.66 for the instrument, it was 0.92. The criteria for Bartlett's test of sphericity were also met, obtaining a result < 0.001, which reveals that the factor analysis carried out is very useful (Table 4).

The total explained variance of the items applied to teachers of the Metropolitan District of Quito is obtained from the applied instrument, results extracted with IBM – SPSS.

Table 4. Total variance explained

Components	Initial eigenvalues			Sums of charges squared of the extraction			Sums of charges squared of rotation		
	Total	% variance	% accumulated	Total	% variance	% accumulated	Total	% variance	% accumulated
1	6,4	53,793	53,793	6,455	53,793	53,793	3,734	31,118	31,118
2	1,9	16,205	69,998	1,945	16,205	69,998	3,028	25,231	56,349
3	0,6	5,509	75,508	0,661	5,509	75,508	1,216	10,131	66,479
4	0,5	4,496	80,004	0,54	4,496	80,004	1,094	9,115	75,595
5	0,4	3,909	83,913	0,469	3,909	83,913	0,998	8,318	83,913
6	0,4	3,679	87,593						
7	0,3	2,747	90,34						
8	0,288	2,397	92,736						
9	0,279	2,325	95,061						
10	0,238	1,985	97,046						
11	0,194	1,614	98,66						
12	0,161	1,34	100						

Note. Taken from the IBM SPSS statistical package, total explained variance of the instrument applied to teachers

In the table section, the amount of variance explained by the initial solution is presented. In this solution, two factors with eigenvalues greater than 1 are identified, which together represent almost 70% of the variability of the original variables. The subsequent section of the table shows the amount of variance accounted for by the factors before rotation. In this extracted solution, the cumulative variance explained by these three factors reaches approximately 84%, a figure similar to the initial cumulative variance. The right section of the table presents the rotated variance loadings, in which the variance ranges around 31% in component 1 and approximately 25% in the second component (Table 5).

The table shows that components 1 and 2 have high values, greater than 0.5 and 0.87 respectively, for items 10, 9, 8, 11, 7, 3, 12 and 5. This indicates that the use of digital narrative is appropriate and supported by these elements in the learning of Social Studies, of the students from the North District 17D05.

The Varimax rotation method was applied which, according to Nair & Yunus [2]. The aim is to optimize the weighting assignments at the level of each factor, so that each element or variable is represented exclusively in one of them. This is done with the intention of minimizing the number of variables present in each factor.

With the analysis of the results obtained from the application of the survey to the teachers under study, we proceeded to the training stage in different scenarios, to subsequently replicate them to their students, obtaining the opinion of the teachers, through the observation sheet, that the use of digital tools in the context of the subject motivates students to develop significant learning.

Considering that the evolution of technology has been a key factor in the educational context, it is necessary to implement didactic strategies according to the interests of

Table 5. Rotated component

ITEM	Components	
	1	2
10. Do you think that the use of digital narrative in teaching Social Studies allows us to understand the world in new ways and facilitates the communication of new ideas to others?	0,866	0,164
9. Can narrative texts be implemented in teaching, aimed at transforming the teaching of Social Studies, generating new actions or methods to achieve educational objectives?	0,857	0,205
8. Do you consider that digital narrative helps in the assimilation, retention and construction of students' knowledge?	0,851	0,251
11. Do you consider that the implementation of digital narratives allows students at all educational levels to be creators of their story, tell it, explain the changes that have been produced in it?	0,73	0,171
7. Do you consider that the use of interactive teaching strategies such as digital narrative generate dynamic and participatory learning?	0,653	0,219
3. Do you create digital stories with the purpose of complementing and strengthening your students' learning?	0,163	0,85
1. Do you use interactive digital stories in your Social Studies classes?	0,187	0,823
2. Do you use digital narratives that involve multimedia language to awaken the interest of your students?	0,228	0,82
5. Do you implement digital stories that strengthen belonging and national identity in your students?	0,183	0,706
6. By applying digital narratives, do you consider that your students improve their digital skills?	0,43	0,317
12. Would you agree to implement digital storytelling as new ways of telling stories that transcend known limits, where the students lose their passivity and become a participant in the story?	0,48	0,174
4. Do you use digital storytelling to explore the most significant historical processes and improve skills in the area of Social Studies?	0,065	0,343

Note. Taken from IBM SPSS statistical program, rotated component

children and young people in the process of training at different educational levels, being the digital narrative an innovative technique to awaken the interest of students, especially in theoretical knowledge with the aim of transporting them in time and live past events relating to the current experience, which allows the consolidation of significant learning in the education process, according to Herman A. [6] in the last decade, the use of technology in the educational sector has advanced significantly, linking it with creativity, analysis, reflection and self-learning of students.

The use of digital tools in the educational process is a reality, at all levels, the advance of technology has led to the need to use innovative didactics that capture the attention of students. In this context, "The representation of reality is approached with new, adapted and hybrid formats" [14]. For which a dynamic approach is required. It is

a changing context, in which participatory interaction strategies are integrated with the use of technology, allowing the student to relate purely theoretical knowledge to reality.

Considering that the progress of ICT has been a predominant aspect in the field of education, it is necessary to implement didactic strategies in according to the interests of children and young people in the process of training at different educational levels, being digital narrative a creative technique that awakens the interest of students, especially in theoretical knowledge with the aim of transporting them in time and live past events relating to their current experience, which allows them to consolidate significant learning in the education process.

Currently, the criterion that the improvement of educational quality is linked to the training of teachers as an obligation of the State still persists; However, a considerable percentage of this population uses ICT as a fundamental tool to implement digital strategies aimed at improving the educational process, "during the process of applying digital narrative and with the endorsement of the results obtained, it was observed that this strategy, in addition to being useful to facilitate learning in the handling of fractions, it can be applicable not only in mathematical content but in any educational area" [15].

The use of different teaching strategies with the application of digital narratives in the teaching of Social Studies is very interesting since students develop digital skills that awaken the interest and creativity of the students, at the same time that the teacher improves their skills to develop innovative techniques, because digital tools give better access to the teaching process, considering the characteristics of the students, their development and the environment in which they operate [15].

5 Conclusions

The analysis carried out using the IBM-SPPS package which has allowed establishing the relationships that are promoted between the Digital Narrative and Social Studies Learning variables, as well as the intrinsic factors that are not observed, it is inferred:

Exploratory Factor Analysis has played a crucial role in verifying the internal structure of the items used, as well as helping in their selection and giving meaning to the data set obtained.

The use of Digital Narratives in the teaching of Social Studies by teachers in Educational District 17D05, located in the city of Quito, province of Pichincha, Ecuador, has a positive impact. These innovative resources awaken the interest of students and facilitate the consolidation of meaningful learning.

It highlights the expectation and commitment that the creation of innovative teaching resources, specifically digital narratives, has generated in teachers, and emphasizes how these resources are valuable to guarantee that students acquire useful knowledge in their academic training.

However, there were limitations in the study, in some cases due to the limited time teachers dedicate to their training, and on the other hand the incipient use of ICT, which leads to research, aimed at offering teaching strategies to students. Teachers so that the teaching-learning process is emotional, with the active participation of students.

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Improving English Language Skills with a Technological Approach in Teaching

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Abstract. Worldwide, the teaching of the English language has gained strength and attitude as it is the most studied and spoken language in the world, whether as a first language or a second language. However, it has been seen that the process of teaching the English language presents certain shortcomings in promoting the development of the four skills (listening, reading, writing and speaking) in students by identifying the lack of digital platforms in the extension of skills. The objective of the research is to validate the use of a digital platform through activities that promote the development of the four skills of learning the English language in students. The use of the platform is promoted through activities aimed at teaching the language, develop each of the skills in Basic Education students. For this research, the mixed methodology was used that combined the qualitative and quantitative approach with a population of 59 students, which allowed an evaluation of the pre-test and post-test to evaluate the development of skills, obtaining a value of 6.82. In the pre-test and a value of 8.77 in the post-test. When measuring the effect of this statistical improvement, it is calculated using Cohen's d, which determines a very large effect of this improvement. With this result, it is identified that the development English language skills improved significantly after using the platform, both in listening, reading, writing and speaking skills.

Keywords: English · learning · platform and skills

1 Introduction

Learning the English language has become a fundamental skill in the globalized and connected world in which we find ourselves. Having mastery of this language not only offers new educational and professional opportunities, but also facilitates effective communication. However, achieving this proficiency in English requires the development of four interconnected skills: writing, reading, listening, and speaking.

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The present study is focused on improving linguistic skills in English through the implementation of interactive tools, which seek to enhance each skill (writing, reading, listening comprehension and oral expression) in students.

Over the years, this language has become valuable among the population. Therefore, the importance of the English language cannot be underestimated, given the existence of numerous languages around the world. It is important to highlight that English occupies an important place in society, since it is used in all fields of knowledge and human development.

For [1] English is the most spoken language worldwide in 2021, with over 1.348 million speakers worldwide and is widely used in fields such as science, technology, business and entertainment. Of them, approximately 379 are native speakers, while the rest have learned this language as a second language.

For [2] "The development of oral expression with 21st century digital tools in the English as a foreign language classroom: these are new oral competencies and skills in Primary Education", who analyzes the potential of a video debate platform in the line of developing new literacies and oral skills of English as a foreign language for Spaniards, EFL English as a foreign language for Spanish-speaking students in Primary Education; This study positively values the tool to improve their oral production in a foreign language thanks to the use of the online video platform Flipgrid.

It is important to highlight that in the research carried out for [3] Students, through the application of the Quizizz tool, have developed the ability to read and understand texts in English, in the same way [4] In their study "inclusion of the Duolingo platform" resulted in students establishing a goal of monitored work on the platform, achieving adequate self-reflection, through comparison and analysis of their progress.

In another study carried out by [5] The impact of vocabulary practice with Fast English on writing skills in English is observed in the context of foreign language education, incorporating technological methods, specifically as educational software, which has made it possible to achieve the acquisition of vocabulary in English effectively in the writing process, to [6] Technological tools are currently essential, whether for teachers or students, playing a fundamental role in the educational field because they improve the process of both teaching and learning, which is why it is linked to the different didactic strategies.

The proposed research arises from the application of a pretest, in which it is identified that students have a regular level in terms of reasoning, analysis and decision making in problem solving given that they obtain an average grade of 6.8. The test applied is based on determining the level of skills that students have developed in relation to (writing, reading, listening comprehension and oral expression). It should be noted that this test has been validated by expert teachers in the area who analyzed each question in relation to the skills that need to be evaluated.

It was carried out in two phases, the first, through the execution of a PreTest where the level of vocabulary and writing in English was determined and then the material developed for the classes was applied with the students, finally a Post Test was carried out. Executed. The results obtained in the first phase are that the students had a poor level in a large percentage, while the level of the students in the Post Test, after working with the material developed in the classes, yielded satisfactory results.

It is important to highlight, as mentioned [7] that "Technology as a combined tool for teaching English" generates great "motivation and drive", both inside and outside the classroom, establishing links of continuous learning that improve the development of linguistic skills. With a social context, so it can be said that the teaching of the English language has revolutionized its strategies, going from a standard and grammatical structure, to becoming a dynamic, creative and independent learning process, combining technology in the development of communicative skills.

The research seeks to develop linguistic skills such as listening, writing, reading and speaking in primary level students in the third years of basic general education. It should be noted that they manage the didactalia platform, at a basic level and in accordance with the initial evaluation. These have little development of linguistic skills, which is identified when performing an initial test.

Given the above, it is important to highlight it in contemporary education. It is vitally important that students acquire new linguistic abilities and skills, and it is better if they are accompanied by the use of different technological tools, which help develop the four skills such as: listening, writing, reading and speaking.

The article is divided into four sections: the introduction, the bibliographic review, the methodology, the statement of the proposal and the conclusions.

2 Literature Review

TIC for [8] constitute a set of associated technological resources that allow the adequate registration, treatment, transformation, storage, use, presentation and circulation of information and whose paradigm is computer networks (Internet, Intranets), enabling access to multiple applications such as: electronic applications, electronic chats, teleconferences, virtual libraries, among many others.

For [9] TIC in education has had an astonishing evolution given that it has been strongly marked by the search for super technologies that allow solving different educational problems. Thus, the changes and innovations generated by the pedagogical use of ICT favor motivation, attitudes and socialization of academic content.

According to [10], mention that infopedagogy guides information and pedagogy in multiple learning activities that are part of a global educational design strategy that we want to be collaborative, attractive and fun, in a computer environment; that takes the student to the center of their educational mission. Learning, which focuses on their motivation as well as the context of their skill development and their interactions with their peers through skill development in a computing environment.

Platforms, according to [11] They are virtual environments or specific tools that facilitate the creation of training activities on the network, they integrate different basic tools into an interface so that users can carry out the necessary activities from the same "surroundings". That is, the platform allows access to external resources located in the Internet space through direct links or through navigation tools; it is possible to differentiate between different levels of users, distinguishes between the administrator and the administrator of the space, and the users.

In the educational field, platforms as tools show specific characteristics, allowing the creation and publication of various documents with multimedia elements such as electronic books, hypermedia materials, databases, as well as access to external resources

located in the Internet space; Includes individual and group communication tools that allow different activities to be carried out, such as tutoring, creating small discussion groups, highlighting emails, the forum, chat, shared whiteboard or conference life, usually includes spaces in the form of folders or boxes. so that users can consult [11].

For [12], Digital platforms "are electronic systems that are organized through computer applications that have been developed from mobile tools and technologies, with the purpose of offering the best offer for the requested service or product to the user who requests it". In fact, digital platforms are companies that operate simultaneously in dual or multiple markets and use the Internet to enable interactions between two or more different, but interdependent, user groups in order to generate value for at least one of the groups. Something similar occurs when certain platforms can also be considered as intermediary service providers.

In relation to the platforms, we can highlight the educational platform Didactalia, (see Fig. 1), it is a linked educational data website that, through GNOSS cognitive technologies, offers various intelligent educational services aimed at improving processes. Teaching-learning and responding to the needs of the population. Students. Therefore, this learning environment is self-regulated and personalized with predictive evaluation, intelligent activities and games, and a system for constructing new educational narratives, which are generated almost automatically [13].

Fig. 1. Plataforma Digital Didactalia.

For [14], teaching-learning the English language, understands and self-regulates one's own cognitive processes while acquiring new knowledge. This activates the subject-object relationship within the teaching-learning process in a continuous cycle of appropriation, reproduction and production of knowledge. According to [15], The teaching-learning process of the English language is a complex activity composed of two different aspects from a methodological point of view: the acquisition of linguistic knowledge and the formation of linguistic habits and skills. This is largely determined by the pedagogical action of the teacher, that is, the structuring of the methodological organizational content of teaching, derived from the main theoretical foundations of pedagogy in relation to philosophical, sociological, psychological, pedagogical, linguistic and didactic. In fact, learning the English language constitutes a fundamental

factor to achieve such purposes, since through knowledge and practice of its functional components, the student will be able to access the content taught or guided by the teacher.

3 Methodology

To develop this study, the ADDIE methodology was applied, as mentioned [16] It is considered a "generic approach" due to its instructional design that can be applied to a wide variety of contexts and situations; due to its flexibility and adaptability. Therefore ADDIE was used to implement the material on the free LMS teaching platform.

The ADDIE instructional design methodology takes into account the added value it proposes and differs from other models in the evaluation process and in a structure that is made up of five phases, which are detailed below: Analysis, the process is established to define what should be done and what type of object of study is oriented, to identify the problem that arises in addition to evaluating the needs of its design and establishing the tasks that will be carried out to be carried out in the design [16].

The Instructional Design is given on the specifications of how it should be carried out with the object of study and To do this, objectives must be established, instruction and development planned, resources identified, and the form of evaluation.

Implementation is where the previous phases are integrated to transform the object of study into a project in the context of the real world. To do this, a pilot test is carried out to identify if the object of study generates the necessary competencies that are specified. in the instructional objective; And finally the Evaluation where it is determined if there is any adaptation of the instructional design.

Includes aspects of interpretation of the evaluation results, the review of activities and the application of satisfaction according to those who completed the object of study.

The following briefly describes how the ADDIE model is applied in the proposal. These phases will be detailed in the proposal according to the activities developed in each of them.

- **Analysis** – Identification of topics to develop.
- **Design** – Structured planning matrix for the design of educational resources.
- **Development** – Development of class planning guides, supported by the development of interactive activities through the 4 skills (Listening, reading, writing and speaking), for implementation on the platform.
- **Implementation** – Implementation of the Digital Didactalia platform and its structures, supported by interactive activities.
- **Assessment** – Application of the Pretest and Post-test evaluation based on the development of English language skills.

It is important to note that the model is applied on the Didactalia platform where resources, books and activities are found. Have been entered such as (teacher's notebook, debates, surveys, opinions of teachers and students), in this space students work online and can develop the four skills in English: listening, reading, writing and speaking, the web application is available for students to learn. As a continuous practice tool, it is constantly open and can be accessed by students, at any time using Internet access and a device such as a tablet, computer or mobile phone.

4 Proposal

Below, the development process of the Didactalia digital platform structured under the ADDIE methodology for the development of skills in learning the English language of basic students is detailed.

4.1 Analysis Phase

As part of the first phase, the English language course content will use the primary education curriculum provided by the Ministry of Education and the external contents used by the institutions published by SM Learning in the linked book "smarty2" will be analyzed". The plan and content of the learning process is determined through the Ministry of Education. In this phase, the students also took a pretest at the beginning of the Sierra school year, which consisted of an evaluation of content related to linguistic skills.

After analyzing the study plan, a list was created with the topics that would be covered, these being:

Topic 1: Numbers 1–10
Topic 2: Colors
Topic 3: Class of objects
Topic 4: Part of the body
Topic 5: Family

4.2 Design Phase

For the Design phase, a dynamically structured matrix methodology is established where the topics are listed to identify resources that allow the development of linguistic skills through the selection of activities that allow defining the planning, see table Nº1. The matrix is structured in the following scheme: Topics, Objectives, Structures, Skills, Names of Tools and Digital Media for Learning English. All of these digital materials have been designed and implemented based on the learning needs of students through the application of online technology. These tools, related to technological media, motivate students to adopt a meaningful approach to learning and support the development of writing, reading and listening. Speaking and speaking skills (Table 1).

Table 1. Structured planning matrix for the design of educational resources.

Nº topics-Nº temas	Topic-Tema	OBJECTIVES					Digital Medium-Medios digitales
		Objectives -Objetivos	Structures-Estructura	Key Language-Lenguaje clave	Skill-Destreza	Digital tools-Herramienta digital	
1	Numbers 1–10	Identifying numbers Identifying and naming numbers 1–10	*Hello! I'm…*	Numbers	Read	Genial-Sanbox	https://acortar.link/pyMcXM
					Listen	Wordwall	https://acortar.link/Yh0h0J
					Write	Liveworksheet	https://acortar.link/UTn2tc
					Speak	Vocaroo	https://vocaroo.com/
2	colors	Identifying colors Identifying and naming colors	*The ____ is _____*	Colors: yellow, red, blue	Read	Wordwall	https://acortar.link/OqCcXq
					Read	Genial-Sanbox	https://acortar.link/ewYMEg
						Jigsawplanet	https://acortar.link/rhxCFF
					Listen	Quizlet	https://acortar.link/ajv29l
					Write	Padlet	https://acortar.link/dZoRkN
					Speak	Vocaroo	https://youtu.be/jYAWf8Y91hA
3	class object	Identifying classroom objects Identifying and naming classroom objects	I am…	Classroom objects	Listen	edpuzzle	https://acortar.link/NkZEPN
					Read	cerebriti	https://acortar.link/rBF4Ox
					Write	Padlet	https://acortar.link/hgY9IO
					Speak	Classroomscreen	https://acortar.link/66tUlN
4	Part of the body	Recognizing and naming the parts of the body	*What's this?*	Parts of the body	Read	educaplay	https://acortar.link/8FQj1s
					Write	Flippity-no realiza en linea	https://acortar.link/gWkZEh
					Listen	Liveworksheet	https://acortar.link/BVFRr7
					Speak	Voice recorder	https://acortar.link/nd6QOG
5	Family	Recognizing and naming family members	*This is ……*	Family	Listen	Liveworksheet	https://acortar.link/wbfZRK
					Read	wordwall	https://acortar.link/Bd7PmF
					Write	Topworksheet	https://acortar.link/yPgQO8
					Speak	Vocarro.com	https://vocaroo.com/

4.3 Development Phase

Following the planning format published by the Ministry of Education, inspired by the themes of the Smarty2 book (numbers, colors, learning objects, body parts and families)

for each lesson plan. Create interactive activities for online applications using the ERCA method.

The ERCA is based on the idea that learning is most effective when students actively participate in constructing their knowledge through direct experience and reflection. This technique is used in experiential education, this learning process applies a wide variety of educational contexts and is not limited to a single field of study. Therefore the ERCA technique, which means "Experience, Reflection, Conceptualization and Application", It is an experiential learning approach. In the first stage, students engage in a practical experience or a concrete activity, which may vary depending on the context and which allows them to apply knowledge and skills in practice. After the experience, students are talented at reflecting on what they have experienced, analyzing their emotions, thoughts and personal observations. Then, in the conceptualization stage, they relate their reflections to theoretical concepts and prior knowledge, trying to understand the meaning and relevance of their experience in the context of the theory. Finally, in the application stage, students use what they have learned to address future situations, making decisions, solving problems, and improving their performance in similar contexts. This methodology promotes deep and meaningful learning through practice and reflection.

In fact, the contribution to the online activity was made through the design of the book for the development and advancement of each of these English improvement tools; As we can see an Example of lesson plan.

With the guidance of the class plan, the following material was prepared for implementation on the platform.

4.4 Class 1

Reading skill. To develop writing skills, use the Sanbox online application according to the plan on the topic: numbers, (see Fig. 2).

In this way, to begin, click on the link and a puzzle will be displayed, (see Fig. 2) in which the student must read the images to assemble, once assembled, the student will be able to read through this interactive application as shown.

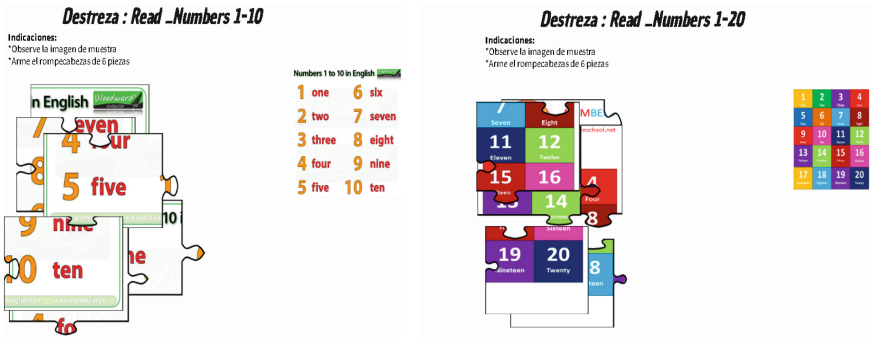


Fig. 2. Interactive activity for reading skills.

Listening skills. This skill develops the way of listening and carrying out the activity that was carried out in the classroom through what was planned on the topic: numbers. In this case, the student uses the online Workwall Application, (see Fig. 3), where the student enters, clicks start and shows some cards, clicks on the card audio, listens and identifies what number.

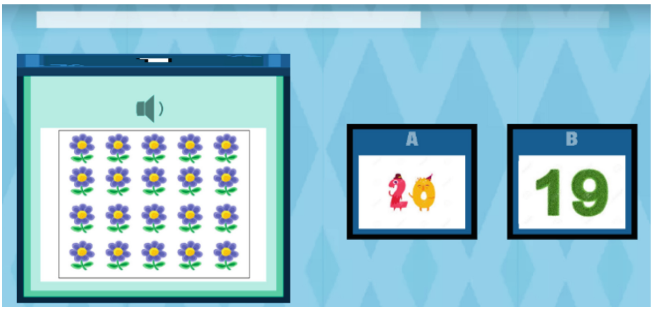


Fig. 3. Interactive listening skill activity.

Writing Skills. For the skill of writing, the online liveworksheet application is used, (see Fig. 4), according to the planned topic: numbers. The student enters the link, reads the instructions, in which she mentions that she must decipher the writing of the numbers in English. When the activity is completed, the student moves to the bottom of the page and clicks on the finished or ending button, viewing the verification of the answers, whether correct or incorrect.

Speaking Skill. In this skill, students tend to express what they have learned in class by planning the topic: numbers. In this section, the student uses the Vocaroo online application (see Fig. 5), where she clicks on the red microphone to start speaking; in this app allows you to record, pause, repeat if necessary, save audio and upload pronunciation link.

4.5 Implementation Phase

The didactalia platform is aimed at the development of English, since teachers design, create and carry out interactive activities. Initially, platform implementations required users and their respective passwords. To continue creating and uploading interactive activities within the platform, activities will be continually developed to help improve your English skills. Likewise, this platform will be distributed thematically according to plan (numbers, colors, class objects, parts of the human body, families).

To enter the platform you must access through the link: https://red.didactalia.net/comunidad/8J5EC. As a testing part of the study, a generic user called studenttesta1@outlook.com has been generated with the following password:123PRUEBA, (see Fig. 6).

Below is a detail of how to enter the name of the didactalia platform through the Google browser.

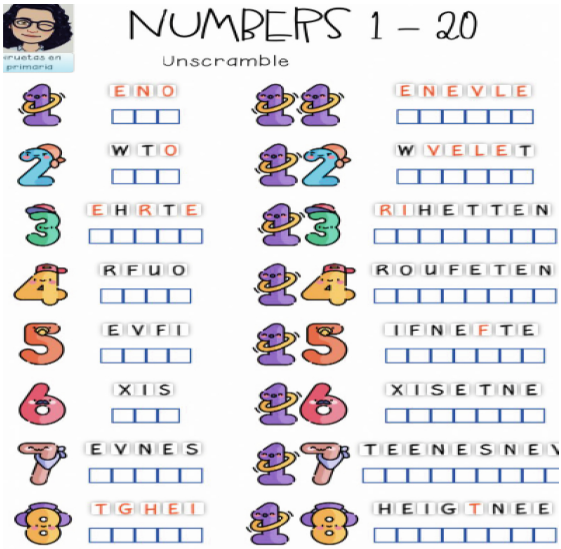


Fig. 4. Interactive writing skill activity.

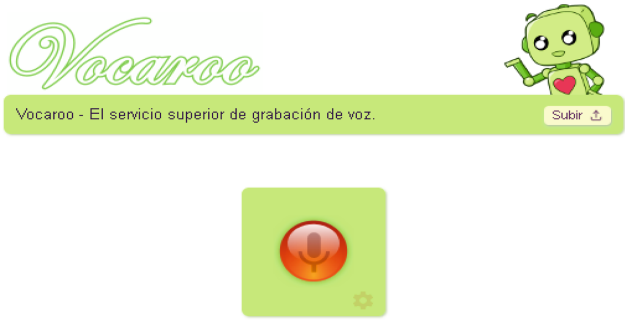


Fig. 5. Interactive speaking skill activity.

Fig. 6. Para ingresar debe insertar el usuario y la contraseña

Within the platform there are different activities that can be carried out such as: Changing the student profile, creating classes, resources (see Fig. 7), class work, books, tests, debate, survey and others. It is immediately detailed below.In the resources section, click to display all the activities that the teacher uploaded to develop English language skills.

Fig. 7. Resources.

Once you click on the label, you will search for the topic of interest (Numbers 1–10, Colors, Class of objects, Part of the body, Family); in this case the first theme "numbers 1–10 and 11–20"; where the reinforcements are found along with the practices in each of the skills (listen, read, write and speak), (see Fig. 8).

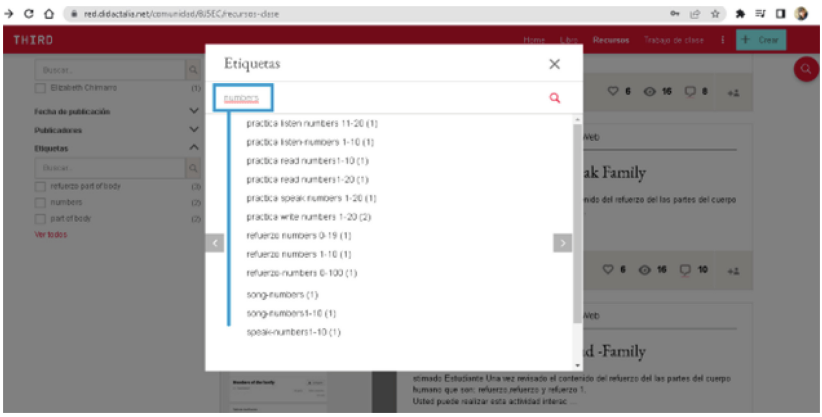


Fig. 8. List of topic activities: numbers.

4.6 Evaluation Phase

View the progress of each activity inserted in the structure of the platform used by students. This includes aspects of interpretation of the results of the evaluation and review of activities. Through this activity I can achieve my research objectives.

The assessment tests were developed based on the skills that students should develop and were validated by experienced teachers, (see Fig. 9).

UNIDAD EDUCATIVA FISCOMISIONAL

"Mariana de Jesús"

Regentada por las Hijas de la Caridad
Cayambe – Ecuador
2022-2023

ENGLISH TEST-COLORS

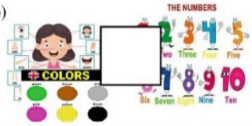
SUBLEVEL/SUBNIVEL:	EDUCACIÓN ELEMENTAL		**CLASS/**CLASE:	Third A-B
AREA: ENGLISH	**SUBJECT/** ASIGNATURA:	ENGLISH	**QUIMESTER/**QUIMESTRE:	1st
STUDENT'SNAME/NOMBRE DEL ESTUDIANTE:			**SCORE/** CALIFICACIÓN:	10
TEACHER/DOCENTE:	Lic. Elizabeth Chimarro	**DATE/**FECHA:		Thursday 27th January, 2022

INDICACIONES: Se incluyen preguntas:
* Metacognición equivalente al 60% (primeras preguntas) ubicar números de preguntas.
* Actividades en las que se evalúa los niveles de logro de aprendizajes equivale al 40% (últimas preguntas)

A.- METACOGNITION QUESTIONS

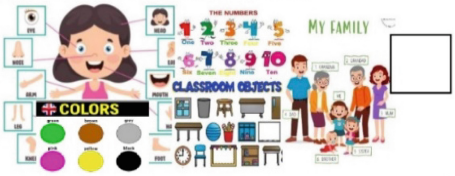
Check as appropriate -Marque según corresponda.

1. **What topic you liked** (Que tema le gusto)



Personal pronouns/pronombres personales **Colors-numbers-body** /colores -numeros-parte del cuerpo **Family**-familia

2. **What did you learn?** ¿Qué aprendió?



Colors -family-numbers-body/colores -familia-numeros-partes del cuerpo **materials/**materiales

3. **Did you like it?**¿Le gusto?

Yes/Si

Not/No

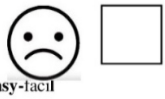
4.How did you learn?(¿Cómo lo aprendió?

Games-songs-guess-(Juegos-canciones-adivinanzas)

I don´t learn-No aprendí

5.- Was it easy or difficult?¿Fue facil o dificil?

Difficult -No entendí



Easy-facil

Fig. 9. Test evaluation

To qualify the proposed evaluation, an instrument is generated based on the four skills that are intended to be developed through the proposal, (see Fig. 10).

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COMUNIDAD DE HIJAS DE LA CARIDAD DE SAN VICENTE DE PAUL
Cayambe - Pichincha
AÑO LECTIVO: 2022-2023

CHECK SHEE

Student name					
Grade : Third					
Teacher:			Elizabeth Chimarro		
Theme:			Smarty Start 2		
Diagnostic activities:			I think, write, read and say		
Date :			25th September ,2022		
Value Porcentaje	Skill-destreza	Parameters to qualify Parametros de calificaciones	Excellent Excelente (2.5)	Good Bueno(1.5)	Regulary Regular(0.5)
25%	Listening	Understand the Instructions in english.			
		Recognize the alphabet			
		Recognize of verbs.			
		Develop evaluation with agility.			
		Pair images with their meaning			
25%	Read	Understand the meaning of read.			
		Maintains order when performing listening activities.			
		Follow instructions			
		Relate vocabulary to images			
		Feel confident when performing the activity			
25%	Write	Use the personal pronouns			
		Know the english structures			
		Write full words			
		Write meaningful sentences			
		Understand the english grammar			
25%	Speak	Difference verbs from common words			
		It has good pronunciation.			
		Feel confident when speaking in English			
		Relate the language to your daily life			
		Question about unknown vocabulary			
Value		**Criteria assessment**		**Performance level**	
9-10		The student has English language skills		Excelente	
6-8		The student lacks English language skills		Good	
0-5		The student does not have English language skills		Regular	

Fig. 10. Check list instrument

And for the validation of the test and the checklist, an instrument was generated, the same one that served for the validation of the evaluation instrument and was applied to professionals specializing in the subject (Table 2).

Table 2. Validation matrix of the instruments applied by 4 specialist teachers

Parameters	Criteria to evaluate								Observations (If a question should be deleted or modified, please indicate)
	Clarity in the wording of the statement		Consistency in the parameters detailed for the evaluation of English language skills		The activities to be evaluated are relevant to the identification of each of the English language skills		The parameters proposed are understood by the teachers		
	yes	no	yes	no	yes	no	yes	no	S/N
Listening	4		4		4		4		S/N
Reading	4		4		4		4		S/N
Writing	4		4		4		4		S/N
Speaking		1	3		4		4		S/N

General Aspects of	si	no	******
The instrument contains clear and precise instructions to respond to the check list.	4		S/N
The Questions allow the achievement of the research objectives.	4		S/N
The number of questions is sufficient to collect information. If your answer is negative, suggest questions to add.	4		S/N

VALIDITY			
APPLICABLE	4	NO APPLICABLE	
APPLICABLE BASED ON THE OBSERVATIONS			

Validated by	MSc Rubí Farinango, MSc Daniela Maldonado , Ing Cristian Quinatoa y Lic Elizabeth Chimarro.	Date: 24/09/2023
Signature:		email:

5 Results

59 third-year primary school students used the proposal. The key descriptive statistics that allow the application of the Shapiro-Wilk parametric test and the lack of normality in the results obtained in both the pretest and the posttest of the computational studies students are identified.

In order to select the statistic to use, we proceed to verify whether the data have a parametric or non-parametric behavior, obtaining the following results (Figs. 11, 12, 13, 14 and Table 3):

Table 3. Descriptive description of results.

Descriptive		
	Pretest	Postest
N	59	59
Lost	0	0
Half	6.82	8.77
Median	6.75	9.00
Standard deviation	0.454	0.775
Minimum	6.12	6.99
Maximum	8.05	10.0

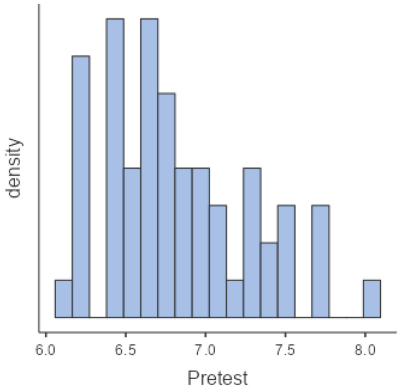

Fig. 11. Density pretest results Graphics

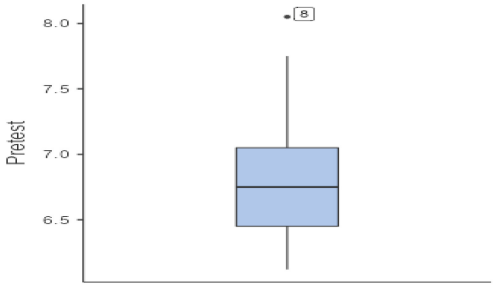

Fig. 12. Pretest result

Having a total of 59 students, the Kolmogorov-Smirrov statistic is used, having a p-value greater than 0.05, where normality is determined in the values of the dependent

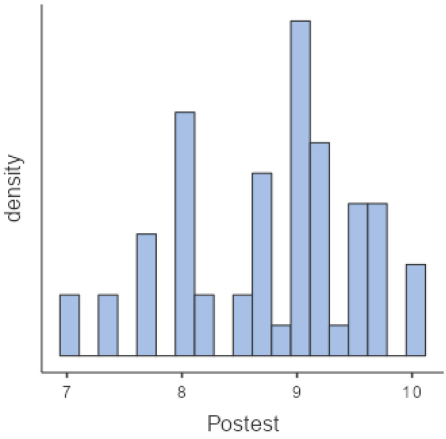

Fig. 13. Density posttest result

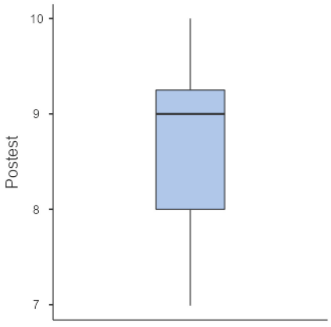

Fig. 14. Posttest results.

variable, so the T - is selected. Student with a confidence level of 95%, with a margin of error of 5% (0.05). Based on the scores of the same group at two different times (pretest and posttest) (Tables 4 and 5).

Table 4. Paired Samples T Test.

Paired Samples T Test					
		statistical	gl	p	D de Cohen
Postest Pretest	T de Student	19.8	58.0	<.001	2.57

Nota. H_a μ Medida 1 - Medida 2 >

Table 5. Additional results

			statistic	p
Postest	Pretest	Shapiro-Wilk	0.949	0.016
		Kolmogorov-Smirnov	0.115	0.412
		Anderson-Darling	0.839	0.029

Nota. Additional results provided by *moretests*

Once a p value of less than 0.01 is determined, it rejects the null hypothesis that the use of digital platforms in English teaching activities does not improve the skills (listening, reading, writing and speaking) of primary school students.

Therefore, the alternative hypothesis is accepted that "the use of digital platforms in English teaching activities develops the skills (listening, reading, writing and speaking) of primary education students." In addition to measuring the effect of this superior statistic, a statistic is calculated from Cohen's d that determines the large effect of this improvement.

6 Conclusion

Once the review of the theoretical foundations of several digital platforms such as: Edmodo, Moodle, Ticking was carried out, it was identified that the most viable for work is the Didactalia platform, as it is a platform that has resources and activities for creation, for the benefit of teachers and students who wish to develop English language skills (listening, reading, writing and speaking) autonomously and flexibly through access to interactive activities created by the teachers themselves.

The instrument was validated by experts; this instrument allowed us to identify the level of skill development (listening, reading, writing and speaking) in each of the students. In fact, once the initial evaluation of the pre-test was carried out, a mean value of 6.82 was obtained, a value that does not reach the minimum score established by the Ministry of Education.

The digital platform was implemented and applied satisfactorily with the students to develop their skills (listening, reading, writing and speaking).

As subsequent work, it is intended to continue applying the Didactalia platform as a support tool for the teaching process of the English subject. After the time of use, the same test that was taken to the students prior to using the platform is applied again, obtaining The following results: average grade of the course in the pre-test 6.82 average grade obtained in the post-test 8.77, which shows a significant improvement. I have demonstrated that the platform is a highly effective resource in the development of language skills. English.

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Didactic Strategy for the Teaching of Educational Robotics and Programming at Secondary Level

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Abstract. This research article focuses on the use of programming through the Scratch program as an educational tool to develop computational thinking skills and robotics in high school students of the Polytechnic High School of the National University of Moreno (ESPUNM). The main objective is to evaluate the feasibility of developing computational thinking in high school students through the teaching of programming with Scratch, emphasizing interdisciplinarity, creativity and problem solving. The methodology comprises two stages. In the first, practical activities were carried out with Scratch, involving students from 11 to 15 years old who are taking the Educational Robotics workshop. In the second stage, a semi-structured observation was carried out and a virtual forum was established for the evaluation of the students, which showed consistency in the data found. After analyzing the results, it was found that the students responded favorably to the teaching strategies implemented in the process. Finally, it is concluded that Scratch is an effective tool for teaching programming and the development of computational thinking, thus allowing to face the challenges of a constantly changing technological context.

Keyword: Robotics · Digital Education · Programming · Computational Thinking

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1 Introduction

In the evolving academic landscape, studies have emerged focusing on the integration of robotics, programming, and digital education. Consequently, schools must adapt their curriculum and teaching methods to nurture the professionals of the future. According to Sánchez, Cózar, and González [1], digital education and robotics serve as potent tools to enhance educational quality and equip students for a rapidly changing world. The authors contend that the challenges revolve around insufficient teacher training, limited school resources, and students' improper utilization of technology. In this context, it is necessary to intervene in the classroom by fostering curiosity, creativity, and problem-solving skills. Block coding is employed to enhance logical thinking, computational diagramming, and cognitive abilities. According to Marroquín, the adaptation of education to individual student needs and skills can be achieved through robotics, which serves as an educational tool to teach STEM-related skills and deepen problem-solving, critical thinking, and social-emotional competencies. Teachers should be prepared to integrate digital technologies and robotics into their teaching and guide students in their responsible and critical use. Involving students in robot construction and programming offers practical learning opportunities and facilitates the application of their knowledge in real-world situations, while also promoting social and emotional skills like collaboration, teamwork, and conflict resolution [2, 3].

In the past decade, the use of block programming, like Scratch, has been increasingly recognized for motivating students and preparing them for the modern world. María Florencia Ripani, the director of Fundación Ceibal, emphasizes the importance of programming as the fundamental language for understanding and changing the digital culture. She encourages educators to adapt their teaching to the current societal context by integrating project-based learning and educational robotics. This approach transforms educational robotics into an active and motivational method, fostering changes in students' attitudes and thought processes [4, 5].

Therefore, the use of active methodologies allows the development of an effective education, in which students are more motivated and learn more effectively with much better results than those obtained with traditional methodologies, since it encourages collaborative and cooperative participation, role distinction, problem solving, creativity, critical thinking and improves autonomy in the construction of learning (Alonso, 2005; Baró, 2011; Morón, 2011) [6–8]. Educational robotics comes to the secondary level as a concrete way to bring students closer to the world of the language of technology and its logic, just as we do with conventional reading and writing. A way of learning, reading and writing in this new world, multi-literacy. Mainly, the objective of educational robotics and programming in the first years of secondary school is to lay the foundations for a development in abstraction that requires understanding the technological world from a critical vision, which seeks the freedom of citizens, thought from the premise of "knowing to be able to choose" [5].

2 Related Work

The following is a literature review of researchers who share the same concern about the implementation of digital education, programming and robotics as a transversal axis.

In the proposal entitled: “guidelines for the development of learning environments in robotics through the study of experiences”, which consists of research on the development of new technologies and tools in the field of educational robotics. The objective is to improve the efficiency and effectiveness of teaching and learning in this field. The research design is based on the study of multiple cases; this method is a valuable research tool used to understand the social and educational reality, it allows to record the particularities and conditions of the phenomenon, in order to understand circumstances. The methodological design is based on a documentary review that provides the theoretical foundations necessary to determine the research design and the instruments to be implemented [9].

In the research “learning objectives for education” implemented a curriculum design of digital education, programming, robotics, for the primary level, designed based on the priority learning cores, we reaffirm our commitment to prepare each of the students to build in the present, their future. With learning progressions to favor the development of computational thinking and its approach through programming and robotics. Three levels are presented (level 1, level 2, level 3) of progressive complexity, which are structured on the basis of: On the one hand, the pillars of computational thinking referred to in the approach (abstraction, decomposition, patterns and algorithms), and practices (debugging, collaboration, evaluation and remix) [4]. In the following article entitled “teacher training offers for technology education graduates”, the objective is to improve learning through new technologies, implementing educational robotics projects in curricular spaces also contributes to the design and implementation of innovative pedagogical projects in missionary schools, hence one of the strategies that is prioritized is the methodology of project-based learning that was approached to think the proposals with educational robotics, computational thinking and programming was implemented had about 50 participants [10]. In the systematization of the experience of integration of ICT to the curriculum from the role of the education coordinator, the objective of this model was to transform the learning environments of students and teachers benefiting and strengthening the teaching process, in the integration model implemented some of the strategies were developed to achieve the objectives of systematization and educational practices. The methodological model designed from the constructivist vision aims to develop or describe a series of steps that will allow systematizing the experience or object of research from a qualitative paradigm with quantitative segments [11].

The research on learning experiences of students in educational robotics and programming workshops in secondary education is framed within a qualitative strategy, following the hermeneutic phenomenological method that has its specificity for educational research, as it allows understanding the pedagogical practices from the voice of its protagonists. The objective of this doctoral thesis was to analyze and understand the experiences of high school students participating in educational robotics and programming workshops. According to the results, this study showed that students’ experiences are positive, diverse and dynamic, and that their perception and position will significantly influence their learning process, where those participants with active and reflective perception experienced a greater contribution to their digital literacy and technological knowledge [12].

3 Methodology

The study is conducted in two stages. The first stage, which is exploratory, involves practical activities using the Scratch program. It was carried out between April 10 and July 14, 2023, with students aged 11 to 15 on average, enrolled in the Educational Robotics Workshop at ESPUNM. The first stage aimed to identify student concerns regarding the use of computational thinking in their academic and evaluative training. The second stage consists of semi-structured participant observation. In this stage, a group of students is randomly selected to experiment with problem-solving topics explained through programming. Additionally, a forum is created on the school's virtual campus for subject socialization and observation of how students assimilate the contents. The objective of the study is for students to learn computer programming using the Scratch program. The methodology employed includes discovery learning and guided discovery learning, depending on the complexity of the computational concepts being taught. The goal is to ensure that students' learning experiences are active, meaningful, and enjoyable.

3.1 Participants

Students from the ESPUNM (Escuela Secundaria Politécnica de la Universidad Nacional de Moreno) of the basic secondary level (1st, 2nd and 3rd year) participate. In addition, we have the support and collaboration of other teachers of different subjects (Mathematics, Social and Natural Sciences, English, etc.).

3.2 Materials and Resources

Reading materials on programming published in the school's Virtual Campus were used. Within the classroom, we implemented the use of the projector, notebook, markers, etc. to introduce the topic related to programming and 3D printing environments. The overall project was prepared in the computer room, working in some instances individually and others with the work teams. We also counted on the participation of teachers from other subjects for efficient data collection. As shown in Fig. 1.

Fig. 1. Materials used during the development of the project.

3.3 Procedure

Computational thinking is being evaluated, in most of the different areas, by means of programming elements. From here, an evaluation approach is promoted from the resolution of complex problems, since this thinking is used as a strategy to solve problems. Once the problem was selected, the step-by-step diagram of the different algorithmic instructions to develop the project with the Scratch program was started. As illustrated in Fig. 2.

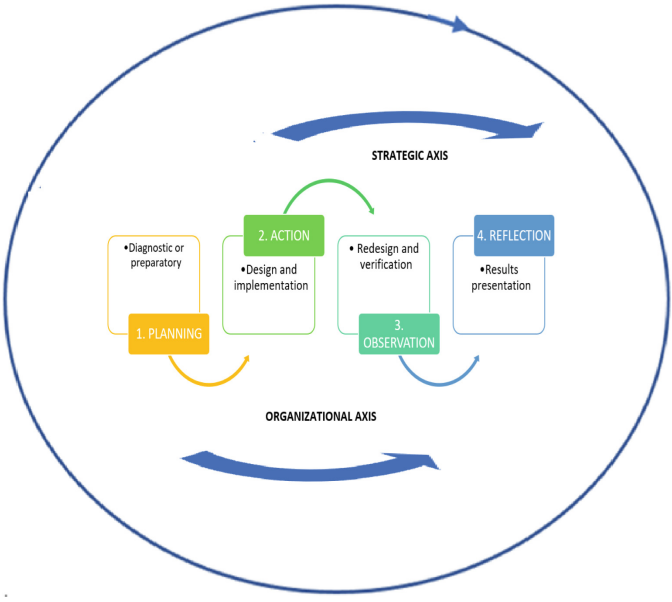

Fig. 2. Action research diagram for the development of the research [13].

3.3.1 Design and Implementation

This research project aims to assess the feasibility of developing Computational Thinking (CT) skills in elementary school students. To this end, we have designed and developed a Scratch initiation guide consisting of various levels of improvement, catering to first, second, and third-year students – beginner, intermediate, and advanced levels, respectively. As for the type of research to be conducted in this project, it is highly likely to begin as exploratory research and later evolve into descriptive or explanatory research. In each phase, we will seek to understand what, how, and why changes occur over time in the development of CT skills, such as decomposition, abstraction, debugging, solution validation, pattern recognition, and more. For the initial data collection (diagnostic assessment), we employed a rubric programmed through Google Sheets to evaluate various indicators and establish the corresponding criteria. The criterion must meet all aspects in order to score a point. Assign a score from 1 - 3 according to achievement against this criterion, 1 being the lowest and 3 being the highest. Secondly, with these data we developed the measurement and analysis of data that was implemented in the didactic strategy during the months of development of this research. As shown in Fig. 3.

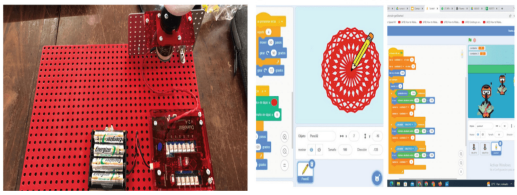

Fig. 3. Guided activities for the use of Scratch.

4 Results and Discussion

In relation to the results of this research, in which the Excel - R data analysis tool was used, the process was carried out from the diagnostic evaluation of the sample to the implementation of the didactic strategy. For this purpose, the measures of central tendencies were calculated, which made it possible to recognize the most prevalent tendency within the questions and to have a more general vision of the tendency in the students' responses to the strategy, facilitating the identification of patterns in the data collected and the consistency of the tool's application. As illustrated in Table 1.

Table 1. Statistical analysis of the sample according to their basic secondary level.

	Courses		
	1RO	2DO	3RO
Standard deviation	0,499	0,618	0,327
Variance	0,249	0,382	0,107

As mentioned above, Table 1 shows that the groups have a low dispersion in their responses, suggesting generally favorable results in relation to the implementation of the strategies. It is worth noting that the third year group seems to have received the process in a more receptive and effective manner, which is reflected in a lower score compared to the other groups. Continuing with the analysis, the standard deviation and variance were used as a measure to quantify the dispersion or variability of the data obtained through the questionnaire. In this context, it is observed that the question that generated the greatest dispersion in the responses was number 7: "Is the UNM involved through the project activities?" This indicates that the students did not perceive significant involvement by UNM in the initial stages of the project. However, starting with the third level group, a greater linkage with the university is perceived. On the other hand, the questions with the least variability are found in question 8: "Is the project interdisciplinary, i.e., was it developed taking into account more than one subject?" Compared to the central tendencies, students perceive that the proposed strategy covers several areas, suggesting that robotics, programming and digital education are effectively integrated as interdisciplinary components in teaching. This is reflected in Table 2.

In the same way, a comparative analysis of the variability among the three level groups (1st, 2nd and 3rd) is carried out, with the aim of identifying which of these groups exhibits the greatest variability in relation to the questions of the proposed questionnaire. The data reveal that the second year group (2nd) presents a greater dispersion and a more marked tendency to move away from the mean, as can be seen in Fig. 4.

It is important to note that, although the graph exhibits a larger deviation in the second year group at 0.618, the results for the most part do not deviate significantly from zero. This suggests a consistency in the data and strengthens confidence in the effectiveness of the implemented strategy. Ultimately, this analysis contributes to fulfill the objective of evaluating the development of the implementation of Robotics in students of Basic Secondary Education who have participated in programming routines with Scratch software, and provides a positive perception about the efficiency of this educational strategy.

Table 2. Questions applied in the questionnaire to the sample.

Items	Frequency distribution			Standard deviation
	Important to	Moderately important	Not important	
Students were involved in the decision-making process to define the activities to be carried out during the development of the project	51,96	44,12	3,92	0,57558
The project is sustainable and viable in the long term as part of the usual dynamics of the Educational Institution	50,98	48,04	0,98	0,52180
Critical thinking and reflection were promoted during the development of the activities	50,00	49,02	0,98	0,52171
Development of PC skills (analysis, logical thinking, algorithmic thinking, looping, information processing, etc.)	54,90	43,14	1,96	0,53963
Resolution of school problems through the implementation of the project	40,20	54,90	4,90	0,57415
UNM is included through project activities	33,33	9,80	56,86	0,92465
The project is interdisciplinary, i.e., it was developed taking into account more than one subject	60,78	39,22	0	0,49064
The project has reached the level of implementing possible solutions to the problem	47,06	50,98	1,96	0,53819
PC skills development (decomposition, abstraction, debugging, solution validation and pattern recognition, etc.)	42,16	51,96	5,88	0,59352
During the development of the activities, collaborative work was promoted	63,73	36,27	0	0,48317

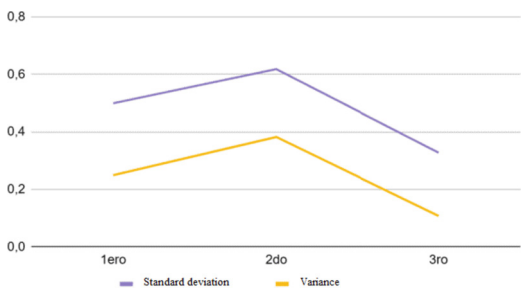

Fig. 4. Analysis of dispersion measures within the participating groups

5 Conclusions

In conclusion, the instrument used in this study has demonstrated a high level of validity and proves to be a suitable tool for assessing computational thinking through problem-solving and programming. The students' results showed a positive reception and effective understanding of the strategy, with low variation among the groups. The implementation of the strategy fostered an interdisciplinary perspective on robotics, programming, and digital education, with the third-year group standing out as the most receptive and effective. The choice of Scratch as a starting point was pivotal as it established a strong foundation in essential programming and logic concepts, enabling students to apply their skills in robot programming. Ultimately, this didactic strategy for teaching programming and computational thinking to students in Basic Secondary Education with prior experience in Scratch is presented as an enriching and effective approach. It facilitates interdisciplinary learning, encourages creativity, and promotes collaboration, preparing students to navigate the dynamic technological landscape. As for the limitations, the study was conducted in a single secondary school with a limited number of students, which restricts the generalization of results to other educational institutions or more diverse student populations. It is recommended that future studies be carried out in more diverse educational settings. Additionally, the study focused on students who were already enrolled in an educational robotics workshop, introducing a potential selection bias due to their differing interests or programming skills compared to the average student population. Lastly, the study had a relatively short duration, and it is suggested that future research allows for long-term tracking of the acquired skills.

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Mapping Methodology Edugramers: A New Field

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Abstract. The use of Instagram in education has aroused the interest of content creators who are dedicated to promoting learning through their accounts, which has motivated the interest of researchers to learn more about the phenomenon of edugramers. Being a new field, there is no fixed methodology to analyze these educational influencers, for this reason, this study explains the mapping methodology used to identify and characterize edugramers in Latin America, addressing the different approaches and methods used to identify these influencers, to contribute to the establishment of clear criteria for their recognition and assessment in the educational field, determining the successes and shortcomings of such research practices. The results suggest that data triangulation is the ideal way to corroborate the information obtained by each research method and that, above all, the researcher's knowledge of the subject will be essential to discern between those profiles that correspond to the research criteria and those that do not.

Keywords: Instagram · Edugramer · Education

1 Introduction

1.1 Edugramer Phenomenon

The edugramer phenomenon is relatively new and arises from the digital era, where technological advances have changed the dynamics of learning [1]. Because of this same novelty, the term edugramer is not yet defined exactly, as it does not appear in English or Spanish dictionaries. However, several types of research have been conducted around these educational influencers [2, 3] and it is on this basis that a definition of the term edugramer is presented as those Instagram users who share educational content on the platform (arts, photographs, videos) to reach a wide audience of students and others interested in learning.

The edugramers were born on Instagram in 2015, when some users began to use the platform to share educational content (especially in the area of languages) and increased the consumption of professional content, breaking with the idea that this social network was only for entertainment [4]. From there, the phenomenon grew and evolved to include a wide variety of topics and areas of study [2]. Currently, edugramers have become an important source of information for students and others interested in online learning.

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1.2 State of the Art

The methodological techniques used to study this group of influencers are mostly quantitative, which generally measure the metrics or the reach of the profiles of these influencers [5]. However, there is also research that analyzes edugramers and the content they publish from a qualitative approach, which enriches the research and provides a more detailed analysis of the phenomenon in question since it is necessary to emphasize that subjects and the content they produce are being studied [4].

Regarding the status of the use of the social network Instagram, data show that it is one of the most popular social networking platforms in the world. The application has more than one billion active users worldwide, with greater popularity in the population aged 16 to 24 [6], ages that correspond to students, both high school and college, which justifies the interest in leveraging the platform for the benefit of education.

According to the Digital 2023 Global Overview Report by Hootsuite and We Are Social [6], in Latin America, the popularity of Instagram has increased in recent years. By January 2023 there were 218 million monthly active users in Latin America. In addition, there has been a growing interest in the consumption of educational content on the platform. Globally, 35% of Instagram users follow education-related accounts. In Latin America, this figure is even higher, with 46% of users following educational accounts on Instagram [7].

To define edugramers it is important to determine the typology of their profiles, as well as to identify and study the publications they make. At this stage, it is convenient to implement content analysis of their publications, evaluate the level of interaction they have with their followers, and recognize the most recurrent topics in their publications. You can also use data analysis tools to determine the reach and impact of your publications. Once these aspects have been pointed out, it is suggested that a mixed approach and triangulation methods be used to reinforce the findings, and to approach edugramers from all aspects that compose them [8, 9]. Apropos of this combination of methodologies, the use of mixed research allows to be able to exploit of the most appropriate tools of the two types and thus, not only to achieve a triangulation of data (corroboration and/or confirmation) but also to be able to discover contradictions or/and get more detailed results. In the words of Charres et al. [10] "researchers will be able to corroborate the information in one or several of the ways outlined above as a type or measure of triangulation, either by employing different sources of data, by employing different perspectives to interpret those data, or simply by employing different methods for the collection of these data." (p. 21).

According to the study by Carpenter et al. [11], users who consume content produced by educational influencers (whatever their platform of diffusion) agree that they can transmit knowledge pleasantly and entertainingly, hence the interest in deepening the use of Instagram in the classroom or as a support for formal learning and encourage the consumption of educational content in more attractive and accessible formats for new generations. Although it is still a new field in the field of education, there are more and more influencers engaged in this work, as well as studies that seek to analyze their activity and perception by users.

This study aims to explain the mapping methodology used to study edugramers in Latin America, addressing the different approaches and methods used to identify these

influencers, analyze their activity, and contribute to the establishment of clear criteria for their recognition and valuation in the educational field.

2 Methodology

This research corresponds to a descriptive study. We used the walkthrough method [12], which allowed us to examine the technological mechanisms, functionalities, and possibilities of using Instagram as a platform through direct interaction with its interface and presentation devices to understand the experiences that can be generated in this environment. This methodological appropriation is justified by the novelty of the research on the figure of the edugramer.

Complementarily, initial objectives and a mixed methodology were proposed to take advantage of the potential of both research methods (quantitative and qualitative) and to study educational influencers in-depth, but from the beginning, it was clear that as the research progresses, the path to follow and how to act in the face of the findings that arise along the way would be discovered. For the convenience of this study, the methodological mechanism of the "cognitive walkthrough" was extrapolated to the survey of the edugramers, and how the application algorithm suggests profiles [13, 14].

The study began with previous research conducted by the authors about instagramers and entertainment YouTubers and also educational influencers on other learning platforms (edutubers). To start with the extraction, some selection criteria were set to have a sample that corresponds to the objectives of the study:

1. That the profiles belong to Latin American countries.
2. That they are not profiles with lucrative or ideological purposes.
3. That the information shared is based on scientific or academic sources.
4. That it publishes educational content at least once a week.
5. That the posts have comments.
6. That the published content is self-created.
7. That the username is congruent with the theme.
8. That the profile has been on the platform for at least one year.
9. It must have a minimum of 100 publications.
10. The account must have at least 2000 followers.

All these criteria were oriented to solidify the profiles found and filter from the beginning those profiles that did not correspond to the concept of edugramer. This is how the extraction of profiles, and the gathering of general information began, a process that took place from July to October 2022, based on three collection methods:

1. **Manual extraction:** based on previous studies, where educational influencers in Latin America are recognized, these users are searched for in the Instagram social network, and a list of possible profiles is generated based on the recommendations offered by the application through similar profiles or accounts suggested by the algorithm. This collection method was the first to be used and was applied for two weeks (August 2022).

2. **Script:** To have a more solid base, programs such as Python and Talend were used to identify edugramers. In the first phase, information was extracted from publications containing the hashtags educacion and educación, using an algorithm to exploit HTTPS requests. The algorithm had configurations to extract information from Latin American and Spanish-speaking accounts (criteria defined to delimit the present research). In a second phase, cleaning criteria were established (number of likes, language, account identifier, public accounts) to filter those profiles that were of interest. With the Talend ETL tool, duplicate publications were eliminated to have one publication per account so that profiles would not be repeated. After the duplicity cleaning, the criteria algorithm developed in Python was applied, which analyzes the publications employing the established criteria and registers only those that meet them. In the final phase 3, an information exploration technique for websites (such as Instagram) was used, which was applied using an algorithm developed in Python, with which information was obtained from the profiles such as followers, followed accounts, total publications, biography, account name, associated website, among others. This method was implemented for two weeks (September and October 2022).
3. **Survey:** A web survey was developed and promoted through social networks (Instagram, Facebook, Twitter, LinkedIn: @utpl, accounts that accumulate more than 100 followers), where educational influencers known by university students were consulted since many young people are looking for edugramers related to their careers to reinforce the knowledge they acquire in the classroom. The survey was launched organically in July 2022, obtaining 39 responses, after which advertising was placed in the networks above, and 123 more responses were added (October 2022) (Fig. 1).

Through these three sources of data collection, reliable information is provided, checking coincidences, and minimizing errors that may occur when only one source of extraction is available.

3 Results

As a result of this research, a general map is presented with the edugramers found, being these results a partial finding of the project "Educational Narratives in Instagram," a proposal of the Communication, Education, and Technology Research Group of the UTPL.

From manual extraction, 58 profiles were obtained (3%), while, with Python and Talend algorithms, it was possible to obtain 2214 results (95%). Finally, 162 responses were obtained in the survey, from which 46 profiles of potential edugramers were found (2%). These three sources of information yielded an overall map of 2318 edugramers (Table 1).

The following is a general analysis of three critical variables of the edugramers' profiles (topic, country, and number of followers). The results are preliminary and represent the 'raw material' yielded by each extraction method without a detailed analysis by the researcher since the aim is to test the methodology for future studies.

Beginning with the subject matter (Fig. 1) and, based on the United Nations Educational, Scientific and Cultural Organization [UNESCO] [15] document on areas of knowledge, most of the profiles deal with topics related to education (39%); within

Table 1. Quantity of profiles found by each extraction method

Source	Quantity	Percentage
Script	2214	95%
Manual extraction	58	3%
Survey	46	2%

this group are the topics of teacher education or training. This finding can be justified by recalling that hashtags such as #education or #educacion set the algorithm's search criteria. Following this are the profiles that discuss Administration, Business, and Legislation (26%) being a recurring theme within the sample. Finally, the remaining topics have a smaller presence, below 10%. However, it is relevant to consider that a large number of profiles (1996) were left out of this graph because no information was found, either because they were private accounts or because, in this first search, mistakes were identified that left them out of the sample, so these percentages are not intended to be representative of the most popular topics for edugramers in Latin America.

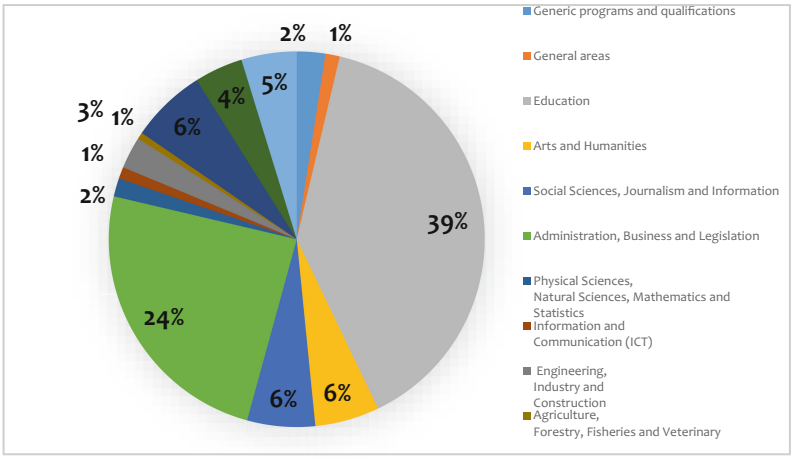

Fig. 1. Knowledge area edugramers sample

As a second variable, the country of origin of the influencers found is determined (Fig. 2), with Argentina being the country with the most representatives within this sample (27%), followed by Mexico (16%) and Colombia (13), countries with high representation or relevance within social networks; the rest of the countries have low representation (less than 10%). It should be noted that, as with the subject matter, most of the profiles in the sample (1244) were omitted from this analysis, as the account's location was not found. Similarly, these findings are not intended to be a faithful representation of edugramers in Latin America, as the sample does not correspond to the total universe of these educational influencers.

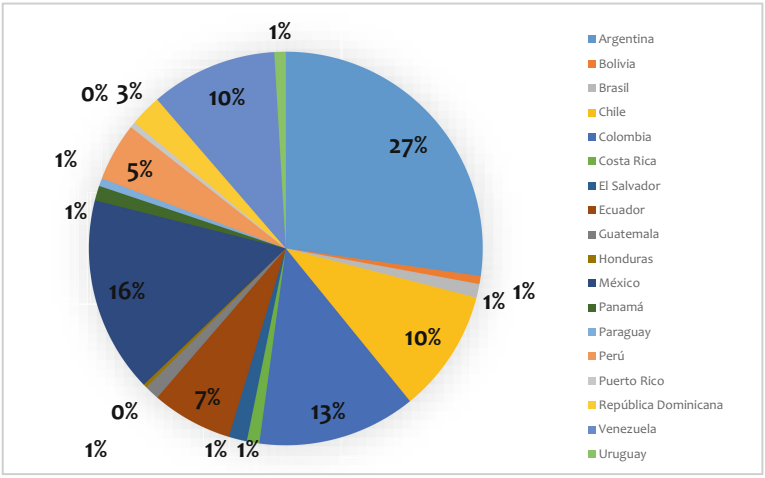

Fig. 2. Country of origin edugramers sample

Finally, we analyze the number of followers of the profiles found to determine the reach of the edugramers in the sample collected in Latin America. Most of the profiles found have fewer than 10,000 followers (70%), reflecting their small audience. However, this is justified since many educational influencers prioritize content over quantity. The other group (30%) has more than 10,000 followers. In a future study, other variables will be analyzed in depth to determine whether there is a correlation between time on the platform and the number of followers or the reasons that justify these differences.

These variables provide a general contextualization of how this sample of Latin American edugramers is made up, serving as a basis for filtering these content creators in subsequent studies, making specific reviews of each profile to perform a content analysis then and thus delve deeper into this phenomenon.

To close this section, it is essential to collect the experiences resulting from the use of these three research methods, presenting a comparison where the limitations and benefits of each of them are discussed for their implementation in future research related to this subject of study or of the same research nature (Table 2).

Table 2. Comparative information extraction methods

Method	Benefits	Limitations
Manual extraction	Information contrasted by the researcher	Limited or redundant information due to Instagram algorithm suggestions
		Data collection takes longer because it depends on the researcher and his or her pace
Script	Greater breadth of information Information validated by computer systems	Information that needs to be further contrasted
		Algorithm error lockouts
		Redundant information
Survey	Stakeholder information in the area, actual audience Provides accurate information about who is consuming the content	Biased or limited information according to the user's experience
		Increased complexity for dissemination
		Depends on the interest or collaboration of the public
		Empty or unrealistic answers that need to be checked
		It needs a budget to advertise it and reach more people

4 Discussion and Conclusions

During the development of the study and testing of the methodology used, some limitations were found that allowed us to determine the effectiveness of each research method. Referring to the manual extraction method, it is worth mentioning that, being an empirical method, it has some flaws in its execution: firstly, to start the search, it is necessary to know at least one example of the sample from which the following are derived; linked to this, the application suggests related profiles that might interest you when you visit an account (Fig. 3).

It is important to note that the algorithm bases these suggestions on the tastes of the internet user who performs the search. Instagram tries to look for similar profiles that can attract attention, i.e., if you look at the profile of a medicine edugramer, the algorithm will throw, in the suggestions, profiles that fit the theme, the country of origin of the account or everything that may be of interest to the user who entered that profile; this limits the search as it implies a bias by not having access to the entire universe of Instagram profiles. This was evident when collecting the information, as there was a preponderance of Mexican profiles from the health area, so the search was stopped with this technique.

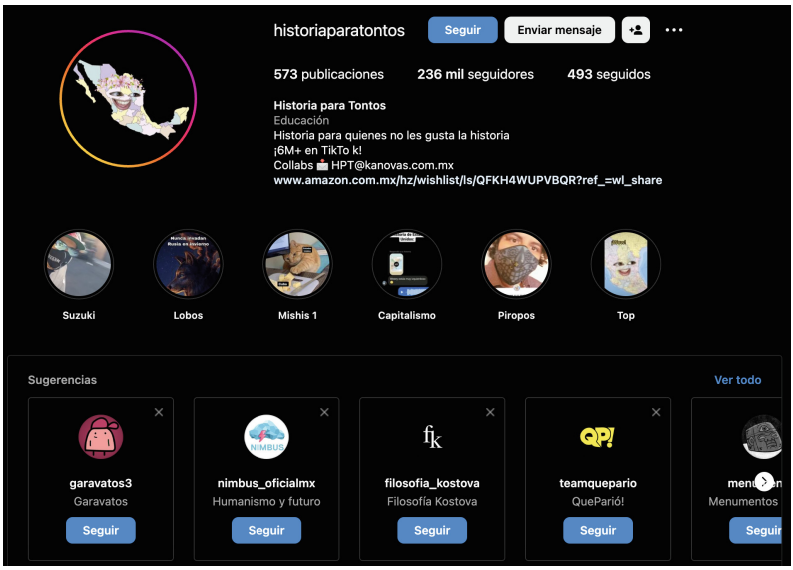

Fig. 3. Profiles suggested by Instagram's algorithm within the @historiaparatontos account

On the other hand, if we point out the limitations of the script, we can contribute that, although it allows us to cover a more significant number of profiles and expand the search to get closer to the universe of edugramers, the profiles found do not always correspond to the ideal ones for the study, since the eye of the researcher is essential to discern between those who do meet the criteria and those who do not. Finally, referring to the surveys conducted, it is concluded that little participation was obtained from users; since being such a specific study, the interest in being part of it is limited, which could be overcome if a reward is offered to those who fill out the survey (holding a raffle with something related to the subject for all those who participate in it), however, those who responded provided interesting profiles that can be a starting point for the first method of extraction (manual search). The limitation of this method is that it should be extended to users from all of Latin America to obtain suggestions of profiles from several countries, which is costly and complicated to achieve.

Preliminarily, it can be mentioned that of 58 profiles extracted manually, all passed the first review, while of the 2214 profiles found through scripts, only 151 passed the first filter, i.e., only 6% were valid. On the other hand, of the 46 profiles obtained in the survey, all were included in the final sample, which indicates that the most successful methods (despite providing the fewest results and involving the most significant effort) are manual extraction and surveys. Despite this, it is concluded that the triangulation and combination of these three methods, added to the researcher's expertise, helps to reinforce the findings because the information is obtained from three different sources, solidifying the findings.

As mentioned in previous sections, the results of this research are the first step in a project that aims to analyze in depth the narratives of educational profiles on Instagram; as a next step, the profiles will be analyzed one by one to filter those that do meet all the

criteria, in addition to providing concepts and divisions that precisely classify educational influencers, and then move to a third phase where a content analysis of the publications of Latin American edugramers will be performed.

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Relationship Between Fatigue in University Students and the Consumption of Videos on Social Networks

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Abstract. The relationship between college student fatigue and social media video consumption is complex. Although watching videos on social networks can be a form of relaxation, excessive consumption can decrease self-control, increasing mental fatigue. The human brain, especially in college students, seeks immediate rewards, making it susceptible to instant gratification from these platforms, leading to mental and physical fatigue. Objective: The study's objective was to establish the relationship between the fatigue of university students and the consumption of videos on social networks. Method: A non-experimental and cross-sectional quantitative analysis was carried out on 137 first-year students of the Catholic University of Santa Maria de Arequipa, Peru. Results: The analysis suggests that only poor self-control has a significant relationship with fatigue in social networks. At the same time, entertainment and the dissemination of unverified information did not show a significant relationship with fatigue on social networks. Conclusions: Although entertainment, poor self-control, and unverified information dissemination are related to social media fatigue in college students, these variables only partially explain the variability in social media fatigue.

Keywords: Fatigue in social networks · poor self-control · dissemination of unverified information · fatigue in social networks

1 Introduction

The digital age has transformed the way we consume information and amuse ourselves. Video-based social networks such as TikTok have become incredibly popular among young people, including college students. Although these platforms offer a variety of content that can be educational and entertaining, they have also fostered a culture of constant consumption that can be harmful.

The relationship between college student fatigue and social media video consumption is complex and multifaceted. On the one hand, consuming videos on social networks can be a way to relax and unwind after a tiring day of studying. However, excessive consumption of these contents can lead to decreased self-control and increased mental fatigue. The human brain, especially at the college student stage of development, is

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hardwired to seek immediate rewards, making it especially susceptible to the instant gratification these platforms offer. This cycle of constant use can lead to a feeling of mental and physical fatigue.

In addition, excessive consumption of videos on social networks can negatively affect students' sleep quality, contributing to fatigue. Many students browse these platforms late into the night, reducing the amount and quality of sleep they receive. Lack of adequate sleep is directly related to fatigue and decreased cognitive function.

On the other hand, fatigue can also influence the consumption of videos on social networks. College students often face high stress and pressure due to the course load and expectations. When physically and mentally exhausted, they may turn to social media as a form of escape and distraction, often resulting in excessive video consumption. Entertainment, central to personal expression [1], has taken on a new dimension in the digital age. The COVID-19 pandemic and the resulting quarantines have led to an increase in the consumption of digital entertainment [2], and young people, in particular, prefer entertainment content, whether media or not [3]. Although entertainment can be a form of relaxation and an escape from routine [4], excessive consumption, especially of content on social networks such as TikTok, can lead to fatigue.

Mathes [5] suggest that content-oriented entertainment reduces the likelihood of high effort engagement, indicating that entertainment content on social media may lead to lower cognitive engagement. Additionally, Whang [6] found that information-seeking, relaxing entertainment, and social interaction motivations are predictors of addiction to TikTok video clips. This suggests a direct relationship between the search for entertainment on social networks and the addiction to these platforms, which may contribute to the fatigue of university students.

Entertainment can also be a valuable tool for learning Alvarez Ramos [7] suggest that entertainment helps relaxation and the unconscious assimilation of content, allowing individuals to learn without awareness. Furthermore, Naerland [8] point out how entertainment can promote basic human capabilities. However, balancing entertainment consumption with other activities is essential to avoid fatigue.

The dissemination of true and false information plays a crucial role in the digital age. Lin [9] maintain that the information is controlled if there is a correct dissemination process. Casino [10] affirms that disseminating information from reliable and doubtful sources presents the same patterns. This highlights the need to adopt measures to prevent and combat the dissemination of incorrect information, as Martínez-Sánchez [11] suggested. The role of the mass media in disseminating information is also crucial, as Urbizagástegui-Alvarado [12] points out, which affirms that they are essential in disseminating new ideas. Chen [13] suggest that an actionable dissemination model can describe a message that will deliver knowledge. However, Perach [14] note that certain sets of motives are associated with variables that predict misinformation sharing, and some of these sets predict social media users' self-reports of having shared misinformation in the past.

Cai [15] suggest that exploring how social robots affect information dissemination mechanisms in social networks is a crucial strategy for network governance. Perez-Dasilva [16] state that spreading false information has become widespread. Fan [17]

point out that although social networks, such as Twitter, have gained popularity in disseminating information about disasters, little is known about the underlying mechanisms that influence the speed and magnitude of disseminating information related to disasters on social networks.

News consumption has also evolved in the digital age. Diaz-Campo [18] suggest that the social consumption of news varies between the incidental reader, who connects for leisure or entertainment, and the routine reader, who monitors the network in search of news of interest. Herencia [19] suggests that official sources can adopt infotainment formats to reach their target audiences without distorting the message.

Self-control is a crucial skill for a person's mental health and well-being. Whelan [20] point out that stress in the form of poor self-control results in different adverse psychological outcomes, such as reduced vitality. Shoji [21] emphasise that the impact is significant even among users who have not received a warning message from the application and even more significant for those with little self-control. This highlights the importance of having good self-control, which, according to Marcelo and Rijo [22], implies various strategies, such as self-instruction, seeking help, or self-consequences.

Mercado and Otero [23] suggest using digital technologies to develop additional skills related to self-control, while Yana-Salluca [24] points out the risk of addiction to social networks, self-esteem, and self-control. Strack Deutsch [25] observes that when self-control is high, people feel less controlled by solid impulses, and Mills [26] suggest that self-control could explain the negative consequences of daily frustration.

In addition, Castillo [27] indicate that the lower the self-esteem and self-control, the greater the risk of network addiction. Koç [28] confirm that poor self-control, fear of missing out (FoMO), and addiction to social media are potential risk factors for youth mental health. Lastly, Krönke [29] point out that poor self-control leads to myopic decisions and incurs severe personal and social costs.

Social media use-related factors, in general, impact the emerging phenomenon known as social media fatigue. Yang Zhang [30] suggests that the possibilities of social networks, such as visibility, persistence, association, and editability, positively influence technological stress, and, in turn, technological stress positively influences social network fatigue. Apuke [31] indicate that information overload and social media fatigue strongly predict misinformation sharing.

Additionally, Qaisar [32] point out that social network fatigue plays a role in mediating the relationship between social network addiction and discontinuous intentions. Li [33] find that privacy concerns and social media fatigue mediate the relationship between perception overload and passive use. Zhang [34] show that information overload, privacy concerns, and time cost strongly impact social media fatigue intention, while compulsive use has a negative impact.

Whelan [35] find that social media use amplifies the effects of information overload on social media fatigue but attenuates the effects of communication overload. Trujillo Pons [36] considers this fatigue, also known as digital or technological, as a booming phenomenon, while Montoya [37] points to a greater risk of developing digital visual fatigue today. Islam [38] hypothesise that social media overload will affect social media fatigue, and Macías [39] indicate that digital reading often causes "digital fatigue". Based on the above considerations, the following hypotheses are formulated: H1 There is a

statistically significant relationship between the dissemination of unverified information and fatigue in social networks; H2 There is a statistically significant relationship between auto-control deficiency and fatigue in social networks and H3 There is a statistically significant positive relationship between entertainment and fatigue on social networks.

2 Methodology

The study presented is a non-experimental, cross-sectional quantitative analysis, meaning that data was collected from a specific population simultaneously without manipulating or intervening in the study group. The population of interest in this case is the first-year students of general studies at the Catholic University of Santa Maria in Arequipa, Peru. The sample selected for the study included 137 students, with a gender distribution of 47.0% men and 53.0% women and an age range of 18 to 29 years, with a mean age of 21.0 years (SD = 1.91). Data collection was conducted in May 2023 using an online survey, suggesting that participants could complete the survey conveniently, which may increase response rates. Importantly, consent was obtained from the participants before completing the survey, which is essential from an ethical perspective. The survey instrument included questions related to four variables: Entertainment (E), Fatigue in social networks (FRS), Poor Self-control (ADV), and Dissemination of unverified information (DINV). Each variable was measured using a 5-point Likert scale, where one indicates "disagree" and five indicates "strongly agree." This allows respondents to express their agreement or disagreement with each statement presented, which can provide a more nuanced view of their opinions and experiences. Finally, the collected data was analysed using PLS-SEM (Partial Least Squares Structural Equation Modeling), a structural equation modelling method that establishes causal relationships between related constructs. This method is beneficial when predicting a dependent variable from one or more independent variables, as in this case.

3 Results

Table I presents the reliability indices of four variables: Entertainment (E), Poor Self-control (ADV), Fatigue in Social Networks (FRS) and Dissemination of Unverified Information (DINV). Several reliability indices are presented for each variable: Cronbach's alpha (α), McDonald's omega (ω), and the Average Variance Extracted (AVE). Cronbach's alpha and McDonald's omega are measures of the internal consistency of a set of items or questions in a survey or questionnaire. A value of 0.7 or higher is generally considered acceptable, indicating that the items measure the same underlying construct. In this case, all the values of α and ω are above 0.7, which suggests an excellent internal consistency for each variable. The AVE measures the variance captured by a construct relative to the variance due to measurement error. A construct is considered acceptable if it explains more than half of the variance of its indicators, with a value of 0.5 or higher. In this case, all the AVE values are above 0.5, which suggests that each construct explains a satisfactory amount of the variance of its indicators (Table 1).

Through exploratory factor analysis (EFA), Table 2 presents the factor loads of the items associated with four different constructs: Entertainment (E), Poor Self-control

Table 1. Reliability of the constructions.

Variable	α	ω_1	ω_2	ω_3	AVE
E	0.80	0.80	0.80	0.80	0.51
ADV	0.79	0.80	0.80	0.81	0.51
FRS	0.74	0.75	0.75	0.75	0.50
DINV	0.87	0.88	0.88	0.88	0.64

(ADV), Fatigue in Social Networks (FRS) and Dissemination of Unverified Information (DINV). These items, represented by E1, E2, etc., correspond to specific questions or statements from a survey designed to assess these constructs. Factor loadings represent the correlation between each item and the underlying factor (or construct) being evaluated. Traditionally, a factor loading of 0.70 or higher indicates a robust correlation between the item and the underlying construct. In contrast, a factor loading of 0.40 or higher is considered minimally acceptable. In this analysis, most factor loadings are more significant than 0.50, suggesting an adequate correlation between the items and their underlying constructs. However, some items, such as ADV3 and FRS4, have lower factor loadings, indicating that these items might need to capture the underlying construct more than the others. The "Unique" column in the table represents the unique variance of each item, that is, the portion of an item's variance that is not shared with the other items in the analysis. Higher uniqueness values indicate that an item is capturing information that is not captured by other items in the analysis. In this case, the uniqueness values range from 0.25 to 0.67, indicating a moderate amount of unique variance for each item.

Confirmatory factor analysis (CFA) was carried out using the maximum likelihood (ML) method for continuous data, and various goodness-of-fit indices were evaluated to determine model quality. One of these indices, the Standardized Root Mean Residual (SRMR), measures the magnitude of the error the proposed model can reproduce. The acceptance criteria for this index are $\leq$0.08 for an acceptable fit and $\leq$0.06 for a good fit [40]. The value obtained for the SRMR was 0.05, indicating that the model has a good fit. Another important index is the Root Mean Square Error of Approximation (RMSEA), which assesses how close the proposed model is to a perfect model. The cut-off points for this index are $\leq$0.08 for an adequate fit and $\leq$0.05 for a good fit. In this case, the value obtained for the RMSEA was 0.07, which suggests that the proposed model has an adequate fit. Considering these indices when interpreting the results is crucial since a good model fit is essential to validate the conclusions derived from the analysis.

Concerning the goodness of fit indices, the Comparative Fit Index (CFI) measures the model's incremental fit. The acceptance criterion for the CFI is $\geq$0.90 for an adequate fit and $\geq$0.95 for a good fit. The value obtained for the CFI in this study was 0.93, which indicates a good fit for the model. The Tucker-Lewis Index (TLI) is another measure of incremental fit, with cut-off points similar to the CFI ($\geq$ 0.90 for an adequate fit; $\geq$0.95 for a good fit), and the value obtained in this case was 0.92, indicating a good fit again. In addition, the Bentler-Bonett Normed Fit Index (NFI) obtained a value of 0.95,

Table 2. Factor loadings.

	Factor				Unique
	1	2	3	4	
E1		0.65			0.51
E2		0.71			0.52
E3		0.73			0.41
E4		0.69			0.46
ADV1			0.59		0.55
ADV2			0.77		0.40
ADV3			0.46		0.67
ADV4			0.76		0.33
FRS1				0.51	0.63
FRS2				0.80	0.38
FRS3				0.68	0.46
FRS4				0.54	0.47
DINV1	0.70				0.51
DINV2	0.85				0.25
DINV3	0.83				0.32
DINV4	0.83				0.30

Note. The 'Minimum residue' extraction method was used in combination with an 'oblimin' rotation

suggesting a good fit. In contrast, the Goodness of Fit Index (GFI), which measures the relationship between the hypothetical model and the covariance matrix observed, obtained a value of 0.97, which strongly supports the goodness of fit of the proposed model.

Table 3. Parameters estimates.

Pred	Dep	Estimate	SE	95% Confidence Intervals		β	z	p-valor
				Lower	Upper			
E	FRS	0.15	0.11	−0.06	0.37	0.15	1.40	0.160
ADV	FRS	0.50	0.13	0.24	0.75	0.52	3.82	<.001
DINV	FRS	0.14	0.08	−0.01	0.30	0.17	1.78	0.075

Table 3 presents Parameter estimates for the variable Entertainment (E) as a predictor of Fatigue in social networks (FRS). The estimate (beta) is 0.15, with a standard error

(SE) 0.11. This means that a one-unit increase in E is associated with a 0.15-unit increase in FRS. However, the 95% confidence interval for this estimate ranges from −0.06 to 0.37, indicating that we cannot be sure the proper relationship between E and FRS is valid and harmful. The p-value is 0.160, more significant than 0.05, indicating that we cannot reject the null hypothesis that there is no relationship between E and FRS at the 5% significance level. For the Poor Self-control variable (ADV) as a predictor of FRS, the estimate is 0.50 with a SE of 0.13. The 95% confidence interval ranges from 0.24 to 0.75, indicating that we can be reasonably confident that an increase in ADV is associated with an increase in FRS. The p-value is less than 0.001, indicating that it is improbable that we would observe this relationship if there were no actual relationship between ADV and FRS. Therefore, ADV is a significant predictor of FRS.

For the variable Diffusion of unverified information (DINV) as a predictor of FRS, the estimate is 0.14 with a SE of 0.08. The 95% confidence interval ranges from −0.01 to 0.30, indicating that we cannot be sure that the genuine relationship between DINV and FRS is not null. The p-value is 0.075, more significant than 0.05, indicating that we cannot reject the null hypothesis that there is no relationship between DINV and FRS at the 5% significance level.

The hypothesis test to determine if there is a significant relationship between the predictor variables (E, ADV, DINV) and the dependent variable (FRS) is based on the p-value obtained in the regression analysis for the variable Entertainment (E), the p-value is 0.160, which is greater than the commonly accepted significance level of 0.05. Therefore, we cannot reject the null hypothesis, and we conclude that there is insufficient evidence to affirm a significant relationship between Entertainment (E) and Fatigue in social networks (FRS). For the Poor Self-control variable (ADV), the p-value is less than 0.001, which is less than 0.05. Therefore, we reject the null hypothesis and conclude that there is a significant relationship between Poor Self-Control (ADV) and Social Media Fatigue (FRS). For the Unverified Information Diffusion (DINV) variable, the p-value is 0.075, more significant than 0.05. Therefore, we cannot reject the null hypothesis, and we conclude that there is insufficient evidence to affirm a significant relationship between Unverified Information Dissemination (DINV) and Social Media Fatigue (FRS). In summary, the hypothesis test analysis suggests that only Poor Self-control (ADV) has a significant relationship with Fatigue in social networks (FRS). In contrast, Entertainment (E) and Dissemination of unverified information (DINV) do not have a significant relationship with FRS.

Figure 1 shows the explanatory model, given that the predictor variables are Entertainment (E), Poor Self-control (ADV) and Diffusion of Unverified Information (DINV); the R^2 of 0.46 indicates that these three variables, together, explain the 46% of the variability in Fatigue in Social Networks (FRS). This means that, although these variables are relevant and significantly impact the FRS, there is still 54% of the variability in the FRS that cannot be explained by these three variables, suggesting that there could be other variables not included in the FRS.

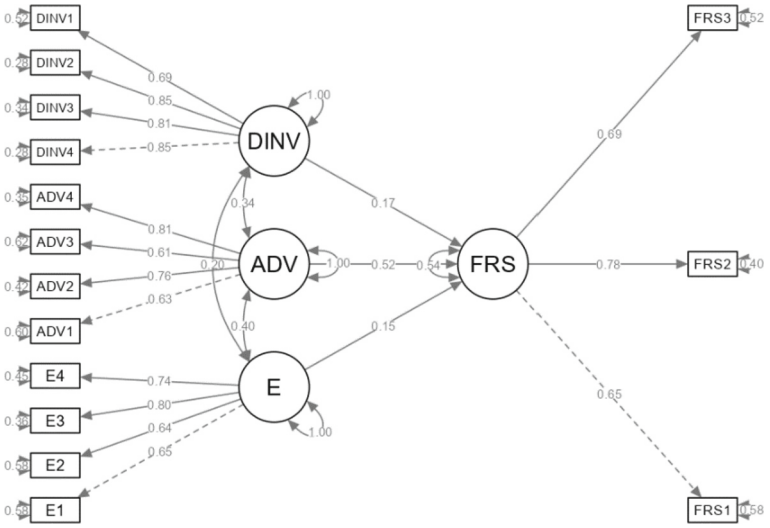

Fig. 1. Path diagrams

4 Conclusions

It is concluded that the variables of entertainment, poor self-control, and dissemination of unverified information impact fatigue in social networks but only explain 46% of the variability in social networks. This indicates that, although these variables are relevant and significantly impact the FRS, other factors not considered in this study also influence fatigue in social networks. Of all the predictor variables, poor self-control showed the most robust relationship with social media fatigue, with a p-value of less than 0.001, indicating that poor self-control is highly likely to be associated with increased social media fatigue.

Regarding the consumption of videos on social networks, the study evaluated the relationship between the predictor variables of the model that video consumption implies and fatigue on social networks. The study proves that entertainment, poor self-control, and diffusion of unverified information are related to Social Media Fatigue among college students. However, since these variables only explain part of the variability, additional research is needed to fully understand the factors contributing to social media fatigue in this population. In addition, more research is needed to understand how social media video consumption relates to social media fatigue.

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