Mathematics Future Classroom Lab to Measure the Affective Domain of Pre-Service Teachers

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Abstract: - The affective domain has a great influence on mathematics learning and academic performance. Therefore, it is important to analyze different variables to propose mathematics interventions that stimulate positive emotion, self-efficacy, and attitude in students. Pre-service teachers (PST) benefit from a novel pedagogical intervention in which they experience a positive classroom environment. The scope of this study is to understand the effects of PSTs by performing an innovative didactic intervention in the future classroom lab (FCL) in a mathematics course.

Key-Words: - Mathematic education, FCL, Learning spaces, Affective domain, Active methodology, Technology, Emotion, Attitude, Self-efficacy.

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1 Introduction

It is known that various affective factors, such as emotion, self-efficacy, and attitude, influence learning mathematics, [1]. Learning is facilitated by positive emotional states, [2]. Emotion is important for mathematics performance and influences the way students approach mathematical problem-solving, [3]. According to research, positive emotions in mathematics are associated with high academic achievement, [4] and promoting positive emotional experiences helps students to reduce the anxiety associated with mathematics, [5]. Self-efficacy is another factor from the affective domain and is one's belief about the own ability to successfully perform the actions necessary to achieve a goal, [6], [7], [8] and is considered an essential element in predicting students' performance in mathematics as well as other cognitive and affective aspects, [9]. Research indicates that learners' success in mathematics is significantly positively correlated with their level of mathematics self-efficacy, [10], [11], [12], [13]. The objective grade alone is not as important as the students' interpretation of their performance when it comes to mathematics self-efficacy, [14]. Students who succeed in a mathematical activity and interpret their achievement favorably, raise their opinion of their mathematical competency, [15]. Attitude is another factor that may affect mathematics learning. Attitude toward mathematics is defined as one's emotional disposition, positive or negative, about mathematics, [16]. The effect of students' attitudes toward mathematics on their learning and achievement is a multifaceted and intricate phenomenon, [17]. Favorable attitudes toward mathematics have a positive impact on learning outcomes, [18], [19]. On the contrary, pre-service teachers (PSTs) negative attitudes toward mathematics have an unfavorable effect on learners' motivation and engagement, [20]. Thus, the importance of the affective domain in mathematics education is evident.

An external aspect that seems to affect learners' affective domain and academic performance is the learning environment. According to some authors, there is a correlation between enhanced students' attitudes in innovative learning settings and higher academic achievement in mathematics, [21]. Also, the classroom environment has an impact on students' self-efficacy, [22]. The physical space of the classroom and the pedagogical style of the teachers are two malleable elements of the learning environment that might influence students' ability beliefs, [6]. Moreover, academic achievement has also been demonstrated to be predicted by students' self-efficacy to self-regulate, or their beliefs about their capacity to manage their work well, [23]. According to the International Society for Technology in Education (ISTE) Report, learning environments need to be active, enabling students to interact and communicate in a way that would be expected of them in the workplace of the future. The authors discussed the idea of active learning to show how combining pedagogy, technology, and physical space may help teachers transform what occurs in the classroom. Classrooms purposefully created with active methodologies enhanced student engagement in comparison to standard classrooms, [24]. Innovative learning contexts, such as the future classroom lab (FCL), aim to provide appropriate physical spaces and motivational technologies for learning. Using technology not only improves students' knowledge, and competencies, but also increases their motivation to learn, [25] as well as their learning process, [26]. It is important to rethink and implement strategies to teach students in such a way that they become interested in mathematics and advocate for interdisciplinary projects and innovative technology for accelerated learning that awakens emotions in students, [27]. The FCL comprises six learning zones: investigate, interact, exchange, develop, create, and present, and the goal is to reconsider pedagogy, technology, and learning environments, [28].

Learning environments and methodology seem to be interrelated and to have an impact on students' affective domain. In recent years, pedagogical and technological changes have also affected learning spaces. There has been an increase in the use of active learning spaces, which allows the physical layout of the classroom to support a learner-centered educational approach, [29]. The purpose of the teacher in active learning is to foster interaction rather than impart knowledge which is possible by the architecture of these venues, [30]. Unlike a standard lecture hall, which largely enables one-sided discourse, the physical design of learning spaces allows for dynamic interactions between learners, [31]. Thus, physical space is considered important by the students for their learning, [32] and students' enjoyment of mathematics is greatly influenced by the learning environment, [33]. The learning environment must provide comfort, safety, and flexibility in a way that facilitates a variety of working styles, interactions, and collaboration between students, [34]. Learners' interest in studying mathematics and their performance are greatly influenced by a pleasant learning environment, [35]. Moreover, the use of novel teaching methodologies has proved to enhance classroom atmosphere, attitudes, and the development of mathematical concepts, [36].

The objective of this research is to analyze the effect of affective domain influences by this intervention proposal in the mathematics FCL. Therefore, by facilitating an intervention based on active methodologies in an innovative learning space supported by digital technologies, the main goal is to reveal the impact on PSTs' affective domain after applying this pedagogical proposal while learning mathematics in the FCL. In the following section, the intervention design and methodology are described.

2 Intervention Design

The intervention has been created considering the different learning zones, which contain the FCL. These areas, within the learning classroom, have been defined as investigating, creating, developing, interacting, presenting, and interchanging and favor collaborative work. The pedagogical proposal aims to work on mathematics contents as well as promote the development of competencies while working in the diverse learning areas of the FCL. During the whole intervention, the students are active in their learning and can move through every learning area, using diverse materials, digital devices, and learning resources that offer the FCL (digital whiteboards, glass wall, video camera, chroma, laptops, mobile phones, etc.). The teacher has the role of facilitator of the PSTs' learning experience, being able to guide them and give constantly constructive feedback to scaffold their learning and help them to achieve their academic goal in a supportive manner. In the first activity, the students should select any base of a numeral system and create a new one by creating novel characters. The activity consisted of designing a numeral system and performing different arithmetic operations. Here, the PSTs may discuss and be able to express any number of the numeral consistently, following the grouping principle in which a new sign represents a certain number of units. Then, the new number system must be represented using a new set of characters, clarifying the relationship between the decimal and planned numeral systems. With this new system, different arithmetic operations must be performed (addition, subtraction, multiplication, and division). For example, participants should draw their number system on the digital board and on the glass wall to share their results inside the mathematics FCL (Figure 1 and Figure 2).

Fig. 1: PSTs create their numeral system in the digital board within the mathematics FCL

Fig. 2: PSTs create their numeral system in the glass wall within the mathematics FCL

Then, to gamify the experience an augmented reality application must be used to create an augmented reality flag, which contains the characters of their numeral system design (Figure 3). Finally, a learning product must be created. It consisted of generating a video recording in the chroma in which students show and resume all the findings developed throughout the session. It permits the teacher to be the facilitator and give formative evaluation through their process and the development of competencies has been promoted throughout the session.

Fig. 3: PSTs create their augmented reality flag in the mathematics FCL

2.1 Sample

The sample consisted of a total of 94 PSTs, 54 participants in the academic year 2021/2022 and 45 in the academic year 2022/2023. Both groups are in the second year of Primary Education degree in the Teacher Training School of the University of Extremadura, Spain. The PSTs were enrolled in the second year of the degree and specifically in the subject ‘Mathematics and its Didactics’.

2021/22							
N	Age	Gender (%)		Educational Background (%)			
		Male	Female	Science	Social Science	Technology	Others
54	20.2	40	60	37	50	7	4
2022/23							
N	Age	Gender (%)		Educational Background (%)			
		Male	Female	Science	Social Science	Technology	Others
45	20.02	40	60	22.22	68.89	6.67	2.22

Fig. 4: Demographic information of the sample

As shown in Figure 4, the sample size is roughly the same and has a similar characteristic regarding the gender distribution. The main difference observed concerns studies background. In the academic year 2022/2023, a total of 68.89% of students has a Social Science background while in the academic year 2021/2022, the percentage is 50%. Therefore, most of the students enrolled in these years for Primary Education degree have a lack of mathematical literacy base.

2.2 Instrument

The data was collected through an online-based questionnaire in concern with emotion, attitude, and self-efficacy towards mathematics and the intervention in the FCL. The questionnaire has been adapted from validated previous research. In Table 1, all the items of the survey are described. A five-point Likert scale was applied, in which the lowest value was “Strongly Agree” and the highest value was “Strongly Disagreed” before and after intervention implementation.

Table 1. Items within the questionnaire.

Emotion items E1. Joy E2. Satisfaction E3. Enthusiasm E4. Fun E5. Trust E6. Hope E7. Pride E8. Uncertainty E9. Nervousness E10. Concern E11. Frustration E12. Boredom E13. Fear E14. Anxiety
Self-efficacy S1. I understand math concepts well enough to teach mathematics at the lower educational levels. S2. I will usually be able to answer students' mathematics questions. S3. When I put my all into it, I will succeed in teaching mathematics as well as I would in other subjects. S4. I believe I have the necessary skills to teach mathematics. S5. Mathematics is useful for solving everyday problems. S6. It is important to know mathematics to get a good job. S7. I know the steps necessary to teach mathematics effectively. S8. I encounter difficulties when trying to explain a mathematical concept. S9. The use of motivating teaching spaces is essential to achieve good learning results. S10. I know how to work in a Classroom of the Future.
Attitude A1. I prefer Classroom of the Future to a traditional theory class to teach mathematical content. A2. I prefer a Classroom of the Future to a traditional lab session to teach mathematical content. A3. Working on the contents of several subjects simultaneously favors learning. A4. Working in a future classroom-type environment enhances creativity in students. A5. Working in a future classroom-type environment enhances collaboration among students.

3 Results

3.1 Reliability of the Instrument's Internal Consistency

The data analysis for this research was conducted through Jamovi software. First, the Cronbach's alpha coefficient (α) was obtained to check the reliability of the instrument's internal consistency. Alpha is the ratio of the variance between the real and observed scores. Consequently, higher dependability indicates a tighter match between the true and observed values, [37]. To show how effectively a set of items assesses a unidimensional latent property, internal consistency was utilized. Because of this, independent coefficient studies were conducted for every domain. For this investigation, the Cronbach's alpha coefficients greater than 0.70 were considered acceptable. The results demonstrate good reliability (Table 2).

Table 2. Statistics on scale reliability, [37].

Scale	Cronbach's alpha (α)
Positive Emotion	0.955
Negative Emotion	0.850
Self-efficacy	0.870
Attitude	0.813

Table 3. Mann-Whitney U test (p-value).

Items	2022	2023
E1	< .001	< .001
E2	< .001	< .001
E3	< .001	0.001
E4	< .001	< .001
E5	< .001	< .001
E6	< .001	< .001
E7	< .001	< .001
E8	< .001	< .001
E9	< .001	0.002
E10	< .001	0.023
E11	< .001	0.404
E12	< .001	0.360
E13	< .001	0.270
E14	0.004	0.057
S1	< .001	0.009
S2	< .001	0.102
S3	0.006	0.691
S4	0.002	0.035
S5	0.028	0.421
S6	< .001	0.905
S7	< .001	< .001
S8	0.006	0.649
S9	< .001	0.597
S10	< .001	< .001
A1	< .001	0.106
A2	< .001	< .001
A3	< .001	0.193
A4	0.003	0.161
A5	0.008	0.429

Therefore, the instrument applied for this research has a good internal consistency for each construct. Second, the Kolmogorov-Smirnov test was conducted to check if the data was normally distributed. As it was not normally distributed, non-parametric tests were conducted. Therefore, the Mann-Whitney U Test was performed to test the existence of significant differences between the mean values. As shown in Table 3, within the column of 2022 year, all the items presented p-values lower than 0.05, which demonstrates a significance in all the items. Whereas in 2023, half of the items presented p-values above 0.05, therefore the results represent non-significance in these items. However, for both years all the items regarding positive emotion were significant. Therefore, applying this intervention the results showed meaningful results regarding positive emotion.

3.2 Analysis of Variance

The analysis of variance for non-parametric data was tested through the Kruskal-Wallis's test. The significance level accepted is 0.05. The hypothesis indicated that H0 = there are no differences between groups and H1 = there exists difference between the groups. Every item presented a significant p-values in the Kruskal-Wallis's test ($p< .005$). Finally, to determine the specific differences between the groups a post-hoc test was conducted. As shown in Table 4, most of the items presented no significant difference except items E11, S8, and S9 comparing post-test 2022 and post-test 2023 the groups presented meaningful differences in their responses, and in item S10 in the pre-test 2022 and pre-test 2023 answers revealed significant differences. Therefore, the items shown in Table 4 are not reliable for reporting significant results due to the differences in the groups.

Table 4. Dunn's Post Hoc comparisons.

Comparison	Item	p	pbonf	pholm
2-4	E11	0.010**	0.060	0.050*
2-4	S8	< .001***	0.002**	0.001**
2-4	S9	0.005**	0.032*	0.026*
1-3	S10	< .001***	< .001***	< .001***

Note: * p < .05, ** p < .01, *** p < .001.
1-3=Pre-test 2022-Pre-test 2023
2-4=Post-test 2022-Post-test 2023

3.3 Exploratory Factor Analysis

Then, the exploratory factor analysis (EFA) has been conducted and represented in Table 5. The factors obtained represent the different variables mentioned before positive emotion (factor 1), self-efficacy (factor 2), negative emotion (factor 3), and attitude (factor 4). The extraction method of factorization along the principal axis was used in combination with an 'oblimin' rotation. After applying the EFA to all the items of the questionnaire, it can be revealed that S9 and S10 have been added and regrouped to the variable attitude.

Factors loadings, variance percentage, and cumulative variance for the factors are represented in Table 5. It showed that four factors positive emotion, self-efficacy, negative emotion, and attitude accounted for 59.1% of the total 29 variances.

Table 5. Factors loadings, variance percentage, and cumulative variance

Factors	Loadings	%Variance	%Cumulative
1	5.50	19.0	19.0
2	4.33	14.9	33.9
3	4.02	13.9	47.8
4	3.27	11.3	59.1

The correlation between the factors is shown in Table 6. The correlations are between 0.247 and 0.404, which indicate medium correlations through the factors. The highest correlation is represented between positive emotion and attitude (0.404). Followed by self-efficacy and attitude and then, positive emotion and self-efficacy.

Table 6. Correlations between factors

	1	2	3	4
1	-	0.346	-0.287	0.404
2		-	-0.323	0.378
3			-	-0.247
4				-

3.4 Mean and Median Comparison

These findings represent the mean and median comparison in the PSTs' responses for pre- and post-test in 2022 and 2023. These results are represented in Figure 5, Figure 6, Figure 7 and Figure 8 for each factor, showing similarities of the sample and more meaningful results in the intervention in the year 2022.

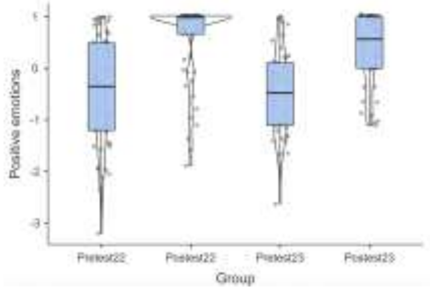

Fig. 5: Mean and median comparison of positive emotion in pre- and post-test in 2022 and 2023

After the intervention in 2022 and 2023, as shown in Figure 5, PSTs perceived an enhancement of positive emotions (joy, satisfaction, enthusiasm, fun, trust, hope, and pride) after the application of this educational proposal in the FCL.

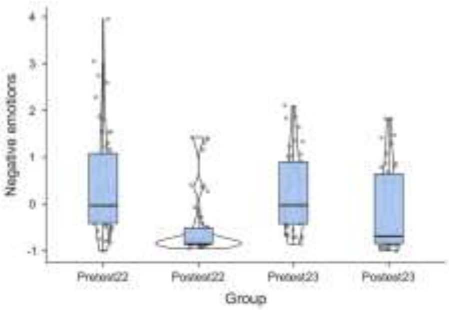

Fig. 6: Mean and median comparison of negative emotion in pre- and post-test in 2022 and 2023

In Figure 6, the results show that PSTs' negative emotions (uncertainty, nervousness, worry, frustration, boredom, fear, and anxiety) have decreased after the intervention in the FCL in both years.

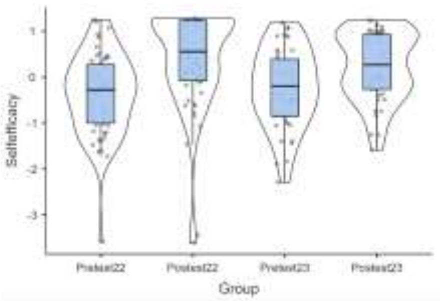

Fig. 7: Mean and median comparison of self-efficacy in pre- and post-test in 2022 and 2023

Regarding PSTs' self-efficacy in concern with mathematics and the FCL, results showed an increase after the application of the intervention in both years (Figure 7).

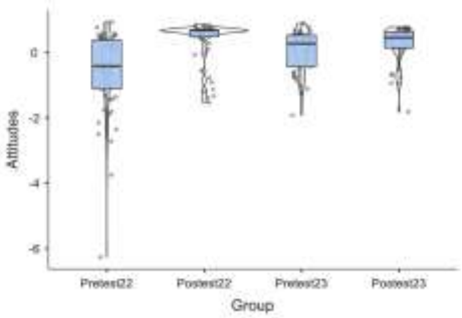

Fig. 8: Mean and median comparison of attitude in pre- and post-test in 2022 and 2023.

Finally, as seen in Figure 8, PSTs reported higher attitudes towards working in a FCL after the intervention.

3.5 Description of Factors and Backgrounds

Here, a descriptive analysis was conducted to obtain the differences regarding the factors obtained and the different backgrounds regarding their previous studies during high school. Number 1 refers to sciences, number 2 to humanities and social sciences, and number 3 to studies concerning technology. Figure 9 represents the average scores, median, and standard deviation for the four factors divided by pre-university studies backgrounds.

	Background	PE	S	NE	A
Mean	1	-0.00462	0.0965	-0.307	-0.118
	2	0.0355	-0.130	0.159	0.0409
	3	-0.0792	0.542	-0.229	0.0910
	4	-0.665	0.454	-0.380	-0.0640
Median	1	0.310	0.0329	-0.706	0.142
	2	0.149	-0.0234	-0.0463	0.435
	3	0.0419	0.661	-0.694	0.425
	4	-0.665	0.454	-0.380	-0.0640
SD	1	1.02	0.779	0.808	0.882
	2	0.947	1.06	0.993	1.00
	3	1.10	0.747	0.832	0.713
	4	0.555	0.915	0.563	1.15

Fig. 9: Description of mean, median, and standard deviation regarding factors and backgrounds

According to the results, based on the different factors and the background, it was revealed some significant data to be highlighted. The PSTs who have a background in technology presented the highest level of self-efficacy. The ones from social science or humanity reported the highest level of negative emotion and PSTs with a science background represent the ones with the highest positive emotion. Finally, in terms of attitude, it is observed that students with a scientific and humanistic background and students with a technological background have the most positive attitude.

3.6 Mean and Typical Error

Figure 10 shows the mean and error for each item analyzed in the pre-test and post-test about the interventions in 2022 and 2023. The axis 'y' represents the degrees of the Likert scale, (1) Strongly Disagree; (2) Disagree; (3) Neither Agree nor Disagree; (4) Agree; (5) Strongly Agree.

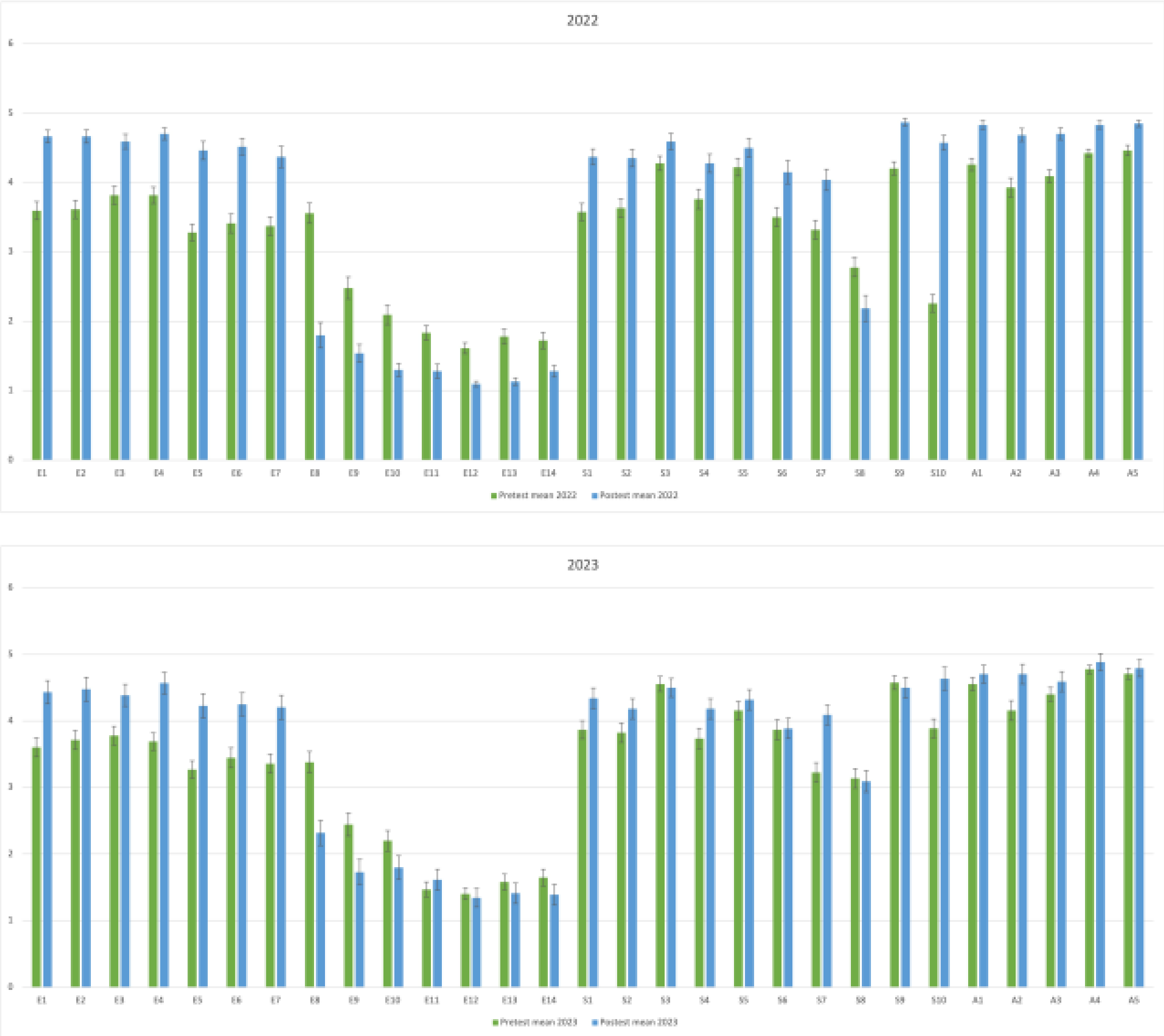

Fig. 10: Mean and tipical error pre- and post-test in 2022 and 2023

There was an improvement in all items after the intervention in both years. The decrease observed is referred to as a negative emotion which after the intervention PSTs have reduced. Item S8 was formulated negatively. For the intervention in 2023, there are fewer differences compared to the intervention of the previous year, but most of the responses in the post-test after the application of the intervention have improved in the PSTs.

4 Conclusion

The effect on PSTs' affective domain regarding the proposed intervention in the mathematics FCL has been analyzed in different aspects. In this research, the instrument internal consistency was reliable for each factor. The results presented significance regarding positive emotion in the two compared years. The factors have been identified and defined more accurately manner and the correlation between them represents the highest correlation between positive emotion and attitude. The findings revealed a global enhancement in PSTs' emotions, attitudes, and self-efficacy for both years of the intervention. Moreover, the differences regarding the factors and the different backgrounds revealed that PSTs with a background in technology reported the highest level of self-efficacy. Factors related to the pre-service elementary school teachers' backgrounds in mathematics influence how confident they feel in their mathematical abilities, [38]. Thus, according to the findings, PSTs who have a technology background are the ones with the highest level of self-efficacy and may feel more confident in teaching mathematics subjects.

According to the various authors, an important factor in increasing teachers' self-efficacy as mathematics educators is their view of the subject and their university experience [39],[40]. Therefore, this study aims to propose learning experiences in the FCL to offer the opportunity to work in different settings and innovative learning environments. In addition, with the use of active methodologies and technological devices. Having this experience in the university may be more likely to enhance PSTs' self-efficacy as mathematics educators in the future.

Mathematics occupies a central place in engineering education and is a fundamental tool in the processes of analysis and calculation that an engineer must carry out. Learning environments and methodology seem to be interrelated and to have an impact on students' affective domain. For this reason, the FCL has been chosen as the scenario for this teaching and learning intervention. To apply a similar proposal in the engineering field, science, technology, engineering, arts, and mathematics (STEAM) methodologies can be applied to propose interdisciplinary projects. This method is advantageous over others that already exist in literature because the FCL promotes the application of and 21st competencies such as problem-solving, critical thinking, collaboration, and digital competence. This permits a more innovative method based on related contents and competencies in teaching/learning practices versus traditional content lessons. Another benefit is that for entering the workforce, the development of engineering students' competencies is a key factor. Also, few works regarding active methodologies and innovative learning spaces have been found. Moreover, this paper can serve as guidance for engineering to do a similar educational proposal applying active methodology and innovative learning environments to foster not only traditional content acquisition but competences acquisition in the FCL in several areas (investigate, interact, exchange, develop, create, and present). In addition, fostering and improving PSTs' affective domain may support them to perform better in the classroom, with the expectation of improved academic performance.

The limitation of this research could be the sample size for each year, to obtain broader results the study will be conducted for more years. Also, this proposal has focused on mathematics. For future research, it can be proposed a STEAM methodology involving these subjects as an interdisciplinary intervention. It can promote research in the engineering field as not many pedagogical interventions are done focusing on learning environments and active teaching-learning methodologies. Then, interdisciplinary intervention can be conducted for future research and can help engineering professors implement new educational strategies in the classrooms.

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