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Introducing Virtual Reality and Emerging Technologies in a Teacher Training STEM Course

Francisco Silva-Díaz [1,2,*], Rafael Marfil-Carmona [3], Romina Narváez [4], Alicia Silva Fuentes [5] and Javier Carrillo-Rosúa [1,6]

[1] Departament of Didactics of Experimental Sciences, University of Granada, 18071 Granada, Spain; fjcarril@ugr.es
[2] Center for Innovation and Teaching Development, Autonomous University of Chile, Providencia 7500912, Chile
[3] Departament of Didactics of Musical, Visual, and Bodily Expression, University of Granada, 18071 Granada, Spain; rmarfil@ugr.es
[4] Departament of Didactics of Mathematics, University of Granada, 18071 Granada, Spain; rnarvaez@correo.ugr.es
[5] Department of Education, University of the Americas, Santiago 8330015, Chile; asilvafu@edu.udla.cl
[6] Andalusian Institute of Earth Sciences (CSIC-UGR), 18100 Granada, Spain
* Correspondence: fsilva@correo.ugr.es; Tel.: +34-603155313

Abstract: In recent years, the adoption of emerging technologies in education (ETE) has significantly grown. However, the effective integration of these technologies remains challenging as many educators have not been afforded the professional/career readiness to properly acknowledge and use them as educational tools. Although the STEM approach has gained prominence in science education, it still requires proper teacher readiness for successful implementation. In this study, with design-based research and mixed-method approaches, a ten-session program for prospective teachers was developed and evaluated to foster the necessary skills and knowledge to effectively integrate different technological resources in STEM education. The program aims to bridge the gap between technology and pedagogy, empowering educators to maximize the use of ETE to enrich learning experiences. The main conclusions emphasize the significance of technology-centric education for future educators, stressing the necessity for teacher training programs that align technological potential with practical classroom applications. Integrating emerging technologies supports contemporary pedagogical approaches like STEM education, promoting active student participation and problem-solving skills. To fully harness emerging technologies' potential, educators need training and support. Developing comprehensive training pathways for these technologies is vital to narrow the gap between technology and effective educational integration.

Keywords: virtual reality; STEM education; initial teacher training; emerging technologies in education; innovation

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1. Introduction

The importance of keeping constant track of the latest trends and developments in science education is critical for educators to provide their students with relevant and effective learning experiences. As the world continues to evolve and new technologies emerge, it is essential that educators keep up to date and prepare to incorporate them in their teaching methods. Along with the critical need for educators to keep up to date, recent literature highlights the importance of incorporating emerging technologies such as virtual and augmented reality, computational thinking, and 3D modeling into science education. This allows educators to provide significant, up-to-date, and effective learning experiences.

Additionally, pedagogical models such as STEM have been developed to provide students with a comprehensive and interdisciplinary approach to science education, emphasizing the integration of Science–Technology–Engineering–Mathematics.

1.1. Science Education and STEM

The integration of STEM education in learning curricula promotes a deeper comprehension of scientific and technological concepts, crucial for fostering 21st-century skills in students. This approach has therefore gained support in educational systems across the globe.

Despite its long integration in the curricula, the concept of STEM education has not yet been universally defined. Bybee (2013) [1] suggests that the diversity of definitions lies in the range of interpretations, with some considering the four disciplines as a collective entity, other times focusing on only one, while others simultaneously engage all four disciplines.

In order to comprehensively understand this approach, perspectives from Shaughnessy [2] and Martín-Páez et al. (2019) [3] are considered. Shaughnessy (2013) [2] posits that STEM education deals with scientific and math concepts and procedures in problem solving, which is maximized with the inclusion of teamwork, engineering design methodologies, and suitable technology. On the other hand, Martín-Páez et al. [3] view STEM education as an approach that fluidly combines conceptual and procedural contents of the STEM disciplines, suggesting a context-dependent prominence of each discipline. This view allows for the dominance of one discipline, guiding the activities within STEM projects according to the specific learning contexts.

One of the significant advantages of STEM education is its role in promoting the development of key competencies essential for success across the fields of Science, Technology, Engineering, and Mathematics. These competencies include critical thinking, problem solving, communication, and collaboration [4–6], as well as computational thinking, programming proficiency, and digital competence [7–9]. These competencies have been and will continue to be invaluable, transcending temporal boundaries, while the incorporation of computer science and technology-related skills further enriches the STEM education landscape. STEM education has also been shown to increase student engagement and motivation, as it provides a more hands-on and experiential approach to learning that connects classroom concepts to real-world applications [3,10,11].

1.2. Emerging Technologies in Science Education

Technologies such as virtual and augmented reality, robotics education, computational thinking, and 3D modeling and printing have evidenced significant improvements in student engagement and success in reaching learning outcomes [12–16]. Thus, it is crucial for educators to keep up to date on ETE advancements and understand their potential to enhance student learning. In fact, research by Meccawy (2023) [17] underscores the importance of exploring teachers' attitudes and concerns about extended reality (XR) technologies before investigating the technology's effect on students' learning outcomes. By addressing these perspectives and fears, teachers are better positioned to adopt new technologies, which in turn contributes to effective teaching practices and improves students' learning [17,18].

Recent scientific evidence highlights the promising potential of virtual reality (VR) as an effective method for giving science lessons [19–22]. A comprehensive review of scientific databases, including Scopus and Web of Science, revealed numerous studies dedicated to exploring this innovative approach [23–27]. These findings evidence that VR has the capacity to improve students' comprehension of intricate scientific concepts, particularly in fields such as biology, chemistry, physics, and earth and space sciences [28–31].

1.3. Initial Teacher Training in the Use of Technologies

The advent of technology in education introduces a new set of complexities and hurdles, predominantly for teachers [32,33]. It is common for educators to feel ill-equipped or deficient in the skills needed to make effective use of technological tools in the classroom. The lack of alignment between the growing demand for technology in educational contexts and teachers' readiness to harness it has emerged as a significant concern [18,34,35].

The emphasis on developing teachers' digital competency is escalating, with a focus on gaining a deep understanding and skills to use technology to its fullest, particularly in delivering quality STEM education [22,36,37]. This urgent need goes beyond basic understanding, encouraging teachers to develop the capability to create, develop, and use innovative technological resources to enrich their pedagogical strategies [38,39].

In the integration of emerging technologies in STEM education, it is crucial to acknowledge that initial teacher training is relevant. However, the focus of such training should not be confined to the usage of these tools alone; instead, it should include strategies to navigate the inherent challenges associated with them [40–42].

Consequently, the main purpose of this study is to design and to evaluate the implementation of a course on the integration of emerging technologies as educational resources for STEM education for initial teacher training. It also aims to evaluate the perception of usability and ease of implementation of technologies for the STEM teaching and learning processes in primary education. The following specific objectives have been proposed:

SO1: To design a complementary training proposal for teachers in initial training that includes the use of emerging technologies as resources for STEM teaching.

SO2: To evaluate the implementation of the training proposal.

SO3: To characterize the opinions of the participants regarding the integration of emerging technologies for STEM education.

2. Method

This research follows a design-based research approach [43], with a quasi-experimental design using a single group [44], with a quantitative phase based on a pre–posttest application. Additionally, it includes a qualitative phase based on the application of a semi-structured interview to the participating students after the completion of the educational proposal. The choice of this type of technique is based on complementarity, highlighted by Hernández et al. (2014) [45], given the need to deeply understand the research results.

2.1. Participants

This study was carried out with 10 students (6 female and 4 male) from the Educational Sciences Faculty of University of Granada (Spain) that voluntarily participated in the course (see Section 3.3). The choice of this group size was determined by the specific objectives and nature of the study, which focused on an in-depth exploration of certain phenomena within a limited scope. Therefore, an intentional non-probability sampling method [46], based on the criteria of accessibility to the sample and interest in participating in the research, was applied. The participants' academic backgrounds (Table 1) encompass a spectrum of academic experiences and levels, ranging from second- and third-year Bachelor's Degree in Primary Education (P01, P03, P04, P05, P06, P07, P08, and P10) to those undertaking advanced studies, including a doctorate in Educational Sciences (P09) and Art and Education (P02). Remarkably, P09, a graduate in Chemistry, currently serves as a research technician, showcasing a strong dedication to scientific exploration. On the other hand, P02, with a background in Visual Arts, presents a distinctive outlook, displaying exceptional skills in digital art and a profound interest in delving into the convergence of technology and ephemeral artistic expressions. Finally, P10 was not able to participate in the interviews, and therefore the number of participants is one lower.

2.2. Data Collection Instruments

The "CUTE-STEM" questionnaire [16], composed of 23 closed-ended items with four dimensions (Table 2) and four open questions, was used. Seventeen items (items 1–5 and 12–23) correspond to a 5-point Likert scale, while six items were dichotomous (items 6–11). The Cronbach's alpha coefficient for the 17 Likert-type items revealed an acceptable reliability score ($\alpha = 0.751$). Also, it included four open-ended questions, aimed to describe the participant's perspectives on aspects related to emerging technologies in STEM education. The questions explore a ranking of 3 technologies for primary STEM education (1), distinctions between virtual and augmented reality (2), perceptions of advantages or disadvantages of IVR in primary education (3), and any additional observations that participants considered relevant (4).

Table 1. Participant profile—gender, age, and academic background.

Code	Age	Gender	Academic Background
P01	23	Female	Bachelor's Degree in Primary Education (third year)
P02	34	Female	Bachelor's Degree in Teaching Art and Visual Communication Master's in Educational Administration PhD Student in Art an Education (second year)
P03	27	Female	Bachelor's Degree in Primary Education (third year)
P04	24	Male	Bachelor's Degree in Primary Education (third year)
P05	19	Female	Bachelor's Degree in Primary Education (second year)
P06	20	Male	Bachelor's Degree in Primary Education (second year)
P07	21	Female	Bachelor's Degree in Primary Education (second year)
P08	20	Male	Bachelor's Degree in Primary Education (second year)
P09	24	Male	Bachelor's Degree in Chemistry PhD Student in Educational Sciences (second year)
P10	21	Female	Bachelor's Degree in Primary Education (second year)

Note: "Bachelor's Degree in Primary Education" refers to "Grado en Educación Primaria" in the Spanish education system.

Table 2. Dimensions and closed-ended item distribution of CUTE-STEM.

Dimension	Definition
(a) Attitude towards technology. (1–5)	This category aims to examine individuals' attitudes and skills towards technology. It involves assessing the extent of their interest in technology, their personal usage of technology, and their technological competencies for educational purposes. This category also involves evaluating individuals' critical thinking abilities when it comes to digital content, such as their capacity to evaluate the quality and reliability of information on the internet and social media.
(b) Frequency of use of Augmented and Virtual Reality for entertainment and educational purposes. (6–11)	This category measures the frequency and purpose of using Virtual or Augmented Reality for personal entertainment or educational activities. It aims to evaluate the degree to which participants integrate technological tools and devices into their daily routine.
(c) Feasibility of using Technologies for STEM Learning in Primary Education. (12–17)	This category evaluates the feasibility of using technologies such as 3D printing, virtual laboratories, augmented reality, immersive virtual reality, educational robotics, and sensors for data collection in laboratory settings. The focus is on assessing the potential practicality and ease of implementation of these technologies in the primary education classroom.
(d) Potential of Technologies as a Resource for STEM Learning in Primary Education. (18–23)	This category refers to the assessment of the potential use of specific technologies for teaching and learning in the STEM fields (Science, Technology, Engineering, and Mathematics) at the primary education level.

A semi-structured interview guide was designed to understand participants' evaluations of technologies in the current context, especially emerging ones in the educational landscape. The interview also aimed to gather student feedback on their course experience and the possibility of utilizing various emerging technologies. Finally, it explored the relationship between teaching methodologies and technology integration. The interviews were estimated to last between 15 and 20 min each.

2.3. The Training Proposal: Immersive Virtual Reality and Emerging Technologies for STEM Education

An integrative didactic experience (the "Immersive Virtual Reality and Emerging Technologies for STEM education" course—IVET&STEM course) was designed and implemented, based on the STEM approach, and tailored to improve the digital competencies required for using a range of emerging technologies such as virtual reality, augmented reality, educational robotics, maker spaces, and sensors, among others, as pedagogical resources for STEM education (Figure 1). This course was developed as part of the Proposed Training Actions for the 2021/2022 academic year at the Faculty of Educational Sciences of the Universidad de Granada, with a duration of 50 h, leading to the acquisition of 2 elective credits for the students (out of the syllabus of the Bachelor's Degree offered in the Faculty: Primary Education, Early Childhood Education, Social Education and Pedagogy).

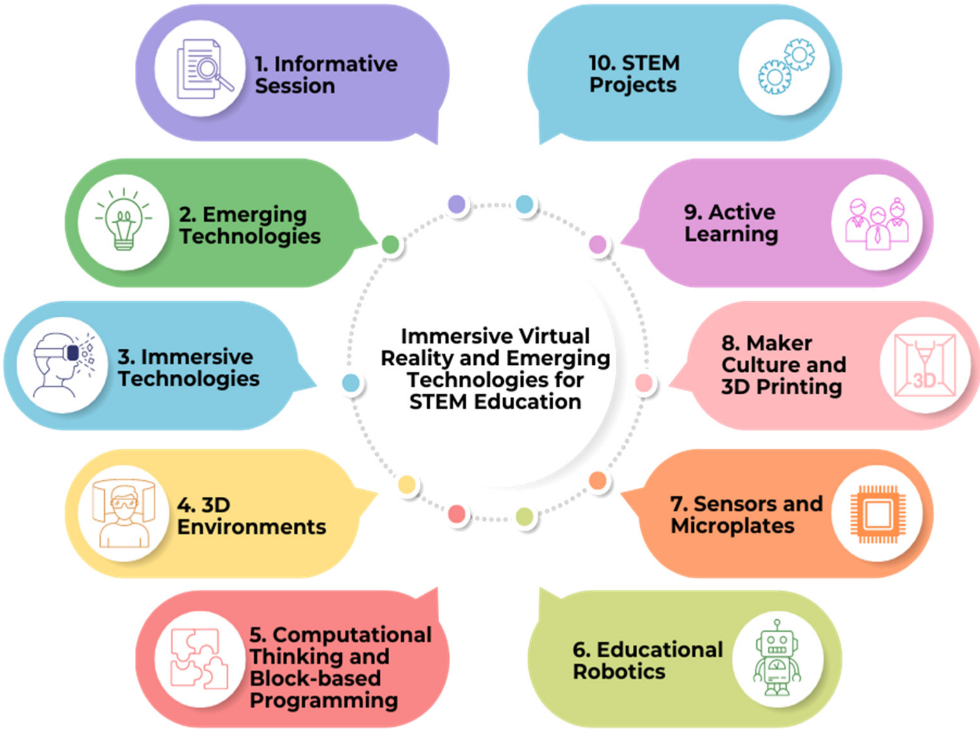

Figure 1. Integrated STEM Learning with Emerging Technologies: Hybrid Training Program for Primary Education Students.

The IVET&STEM course simultaneously promotes the integration of active learning methodologies, such as Inquiry-Based Science Education and STEM teaching approaches. It was executed in a hybrid mode, where the 50 h duration was evenly split between seminars in-person and virtual formats. The 25 h of seminar in-person instruction involved theoretical–practical activities focused on the utilization of various emerging technologies, including virtual reality, robotics, and 3D printing. Additionally, specialized training was provided on using the CoSpaces (https://cospaces.io/edu/, accessed date on 1 August 2023) platform for constructing 3D virtual learning environments, which can be visualized through virtual reality headsets.

2.4. Procedure

After the design of the IVET&STEM course, the outreach of it was performed during September and October 2021 by the Faculty of Educational Sciences website and social media, informational posters, and technology equipment demonstration in the Faculty Hall. The course began on 2 November 2021 with the pretest administration of CUTE-STEM. The last session of the course was on 22 May 2022 when the posttest CUTE-STEM was administered. The semi-structured interviews with the participants took place during the three weeks after the finalization of the course in order to adjust the availability of the participants, and each interview needed between 15 and 30 min.

2.5. Data Analysis

A data analysis of the closed items of CUTE-STEM was conducted through the application of both descriptive and inferential non-parametric statistics (Wilcoxon signed-rank tests) using the SPSS V26 software. A content analysis using MaXQDA 2020 (a qualitative data analysis software developed by VERBI Software, based in Berlin, Germany) was carried out through inductive categorization of the information obtained from the open questions of CUTE-STEM and the semi-structured interviews.

3. Results

The findings are presented separately based on the nature of the data.

3.1. Quantitative Results of CUTE-STEM

The results for the quantitative section of CUTE-STEM are synthesized in Table 3 (Likert scale) and Table 4 (dichotomous items). The pretest descriptive analysis shows the initial student perceptions regarding various facets of the use of emerging technologies in education, and the areas of greatest importance can be highlighted.

Table 3. Statistics for the Likert scale items of CUTE-STEM (1–5; 12–23) by items and dimensions.

	∑		Min		Max		Mo		Wilcoxon		ES
Items	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Sig.**	**Z**	**d**
1. I am interested in technologies	41	47	3	3	5	5	4	5	0.034 *	−2.121	0.848
2. I use technologies in my personal leisure time	42	44	3	3	5	5	4	5	0.414	−0.816	0.268
3. I use technology in my learning process	39	46	3	4	5	5	4	5	0.038 *	−2.070	1.099
4. I have a critical capacity towards digital content (Internet, social media, etc.)	34	43	2	3	4	5	4	5	0.024*	−2.264	1.08
5. I am competent in using technologies	31	39	2	2	4	5	3	5	0.054	−1.930	0.853
12. Feasibility of using 3D printing	31	35	2	3	5	5	3	3	0.157	−1.414	0.463
13. Feasibility of using Virtual laboratories (applications that simulate laboratories)	26	35	1	3	5	5	3	3	0.041 *	−2.041	0.928
14. Feasibility of using Augmented Reality	33	40	1	3	5	5	3	4	0.020 *	−2.333	0.740
15. Feasibility of using Immersive Virtual Reality	33	34	1	2	5	5	3	4	0.660	−0.439	0.093
16. Feasibility of using Educational robotics	36	34	2	2	5	5	4	3	0.480	−0.707	−0.207
17. Feasibility of using Sensors (data collection in laboratories)	28	32	1	2	4	4	3	3	0.279	−1.081	0.559
18. Potential of 3D printing in PE.	43	46	4	3	5	5	4	5	0.180	−1.342	0.499
19. Potential of Virtual laboratories in PE.	45	47	4	4	5	5	4	5	0.317	−1.000	0.395
20. Potential of Augmented Reality in PE.	42	45	3	4	5	5	4	4	0.180	−1.342	0.515
21. Potential of Immersive Virtual Reality in PE.	44	46	3	4	5	5	5	5	0.414	−0.816	0.325
22. Potential of Educational robotics in PE.	48	48	4	4	5	5	5	5	1.000	0.000	0
23. Potential of Sensors in PE.	40	41	3	3	5	5	4	4	0.763	−0.302	0.142
Dimensions	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Sig.	Z	d
A. Attitude towards technology.	187	219	13	15	22	25	20	21 [a]	0.007 **	−2.689	1.127
C. Feasibility of using technologies for STEM learning in Primary Education.	187	210	8	16	25	28	16	18 [a]	0.191	−1.309	0.515
D. Potential of technologies as a resource for STEM learning in Primary Education.	262	273	23	24	30	30	26	30	0.261	−1.124	0.504
Total (A, C & D)	636	702	52	55	72	77	59 [a]	72	0.028 *	−2.194	1.025

Note: ∑: item-level sum; Min: minimum value; Max: maximum value; Mo: mode; ES: effect size based on Cohen's d; *,** statistically significant. [a] There are multiple modes, the smallest value is displayed.

Dimension A, which evaluates attitudes toward technology (max score 50), shows an average sum as high as 37.4. Item 1 ("I am interested in technologies"; ∑ = 41; Mo = 4) is the most valued, indicating the participants' strong technological interest and setting a positive context for the STEM course. However, item 5 ("I am competent in using technologies"; ∑ = 31; Mo = 3), assessing self-perceived competency, is the least valued, suggesting a disparity between interest and perceived proficiency in technology use.

Table 4. Statistics for the dichotomous items of the instrument (6–11).

	f Pre		f Post	
Item	**Yes**	**No**	**Yes**	**No**
6. Augmented Reality for leisure purposes	40%	60%	90%	10%
7. Augmented Reality as a learning tool in a subject	30%	70%	70%	30%
8. Augmented Reality for educational purposes (as a teacher)	10%	90%	40%	60%
9. Immersive Virtual Reality for leisure purposes	20%	80%	80%	20%
10. Immersive Virtual Reality as a learning tool in a subject.	10%	90%	80%	20%
11. Immersive Virtual Reality for educational purposes (as a teacher)	10%	90%	40%	60%
Dimension	**Yes**	**No**	**Yes**	**No**
B. Frequency of use of Augmented and Virtual Reality for entertainment and educational purposes	20%	80%	66.6%	33.3%

Note: f: frequency.

Dimension C, assessing the feasibility of emerging technologies (max score 60), shows an average sum of 31.6. Item 14 (Augmented Reality; $\sum = 33$; Mo = 3) is highly rated, yet item 13 (Virtual Laboratories; $\sum = 26$; Mo = 3) is less so, implying a perceived challenge or unfamiliarity with such technology.

Dimension D, which evaluates the potential use of emerging technologies in primary education (max score 60), shows an average sum of 43.7, the highest of all the dimensions. Item 22 (Educational Robotics; $\sum = 48$; Mo = 5) is the most valued, highlighting the perceived relevance of robotics in education, while item 23 (Sensors in Education; $\sum = 40$; Mo = 4) is the least valued, suggesting a lesser perceived importance or comprehension of this technology in STEM education.

The participants demonstrated substantial interest in technology for leisure and learning, with high perceived potential for emerging technologies. However, concerns about their usability were evident. Given this initially high appreciation, significant post-course improvements could be more difficult to achieve due to the already positive attitudes toward technology. Nevertheless, differences have been found as shown in Table 3 and described below.

Regarding dimension A, a considerable positive shift in the participants' attitudes and skills toward technology was noticed, as evidenced by a significant increase in the overall sum of the items' ratings from the pre- to posttest (from 187 to 219). This statistically significant change ($p = 0.007$), coupled with a large effect size (d = 1.127), suggests the intervention's positive impact. We can identify these positive shifts into specific items: items 1, 3, and 4 showed significant increases from the pre to post phase. For item 1, the total sum responses rose from 41 to 47 ($p = 0.034$, d = 0.848), indicating the intervention effectively enhanced the participants' interest in technology. Similarly, item 3 increased from 39 to 46 ($p = 0.038$, d = 1.099), demonstrating the intervention's role in promoting the use of technology as a learning tool. Item 4 also displayed a significant change, increasing from 34 to 43 ($p = 0.024$, d = 1.080), highlighting its impact on fostering the participants' critical capacity toward digital content.

Moving on to dimension C, the overall increase in the sum of the items' ratings (from 187 to 210) was not statistically significant ($p = 0.191$). However, a medium effect size (d = 0.515) suggests a slight positive trend in the perceived feasibility of using technology in STEM learning contexts among the participants. Specifically, items 13 and 14 showed significant changes. The perceived feasibility of using virtual laboratories (item 13) significantly increased from 26 to 35 ($p = 0.041$; d = 0.928). Similarly, the perceived feasibility of using augmented reality (item 14) demonstrated a significant rise from 33 to 40 ($p = 0.020$; d = 0.740). However, in item 15, there was minimal change, with the sum of the responses remaining stable from 33 to 34 ($p = 0.660$; d = 0.093). The participants still perceived IVR as challenging to implement even after the course intervention. While the overall change in dimension C was not statistically significant, the significant shifts in specific items suggest that the intervention had a potential impact on participants' perceptions of the feasibility of integrating technology in STEM education.

Dimension D received the highest ratings in both the pre- and posttests, indicating the participants' consistent belief in the potential of these technologies for STEM learning. Although the overall change in this dimension was not statistically significant ($p = 0.261$), a moderate effect size (d = 0.504) suggests a modest perceived increase in the potential of these technologies. Notably, items 18, 21, and 22 received consistently high ratings, with item 22, focusing on educational robotics, obtaining the highest scores in both phases (48 out of 50). This demonstrates the participants' unwavering belief in the effectiveness of these technologies as valuable resources for enriching STEM education. While statistical significance was not achieved, the trend in this dimension indicates that the intervention may have reinforced the participants' positive views on the potential of these technologies for enhancing their learning experiences in the STEM fields.

Table 4 presents an analysis of items 6–11. These items are designed to comprehend the frequency of augmented and virtual reality usage for entertainment and educational purposes by the participants.

Before the intervention, engagement with augmented and virtual reality varied across different applications. Augmented reality for leisure showed the highest pre-intervention engagement (40%), while immersive virtual reality and augmented reality for STEM education had the least (10%), indicating limited initial use of these technologies in these contexts.

Table 4 showcases a significant surge in the utilization of augmented reality for leisure purposes, with affirmative responses jumping from 40% in the pre-survey to 90% in the post-survey. This trend suggests greater adoption of AR for leisure purposes among the participants following the intervention. In addition, the use of augmented reality as a learning tool in a subject saw substantial growth, shifting from 30% affirmative pre-responses to 70% post. In the case of immersive virtual reality, for both leisure purposes and as a learning tool in a subject, a considerable increase in affirmative response frequency is observed, from 20% and 10% pre, respectively, to 80% in both cases post. It is important to note that these technologies are emerging in educational settings and may become valuable pedagogical resources in the future.

Building upon the item-specific data, an assessment of dimension B as a whole presents an affirmative shift in the participants' frequency and purpose of using augmented and virtual reality for both personal and educational purposes. Notably, positive responses escalated from a baseline of 20% to 66.7% post-intervention, indicating a substantial integration of these technologies into the participants' daily routines. Concurrently, the negative responses dropped from 80% pre-intervention to 33.3% post-intervention. This improvement underlines the intervention's effectiveness in promoting emerging technology acceptance and application in an educational context, crucial in our technologically advancing era.

3.2. Qualitative Results of CUTE-STEM

The results for the qualitative section of CUTE-STEM indicate several interesting findings. Regarding the first question (three types of technologies or digital devices in increasing order of importance) (Figure 2), in the pretest, the participants predominantly mentioned traditional technologies like "Ordenador" (Computer), "Robótica" (Educational Robotics), and "Pizarra Digital" (Interactive Whiteboard) as positive for STEM teaching. However, in the posttest, there was a noticeable shift toward more advanced technologies such as "Realidad Virtual" (VR and AR), "Impresión 3D" (3D Printer), and "Robótica" (Educational Robotics), which experienced slight growth. This transition suggests an evolving perspective, with the participants recognizing the potential of immersive and maker technologies in STEM education.

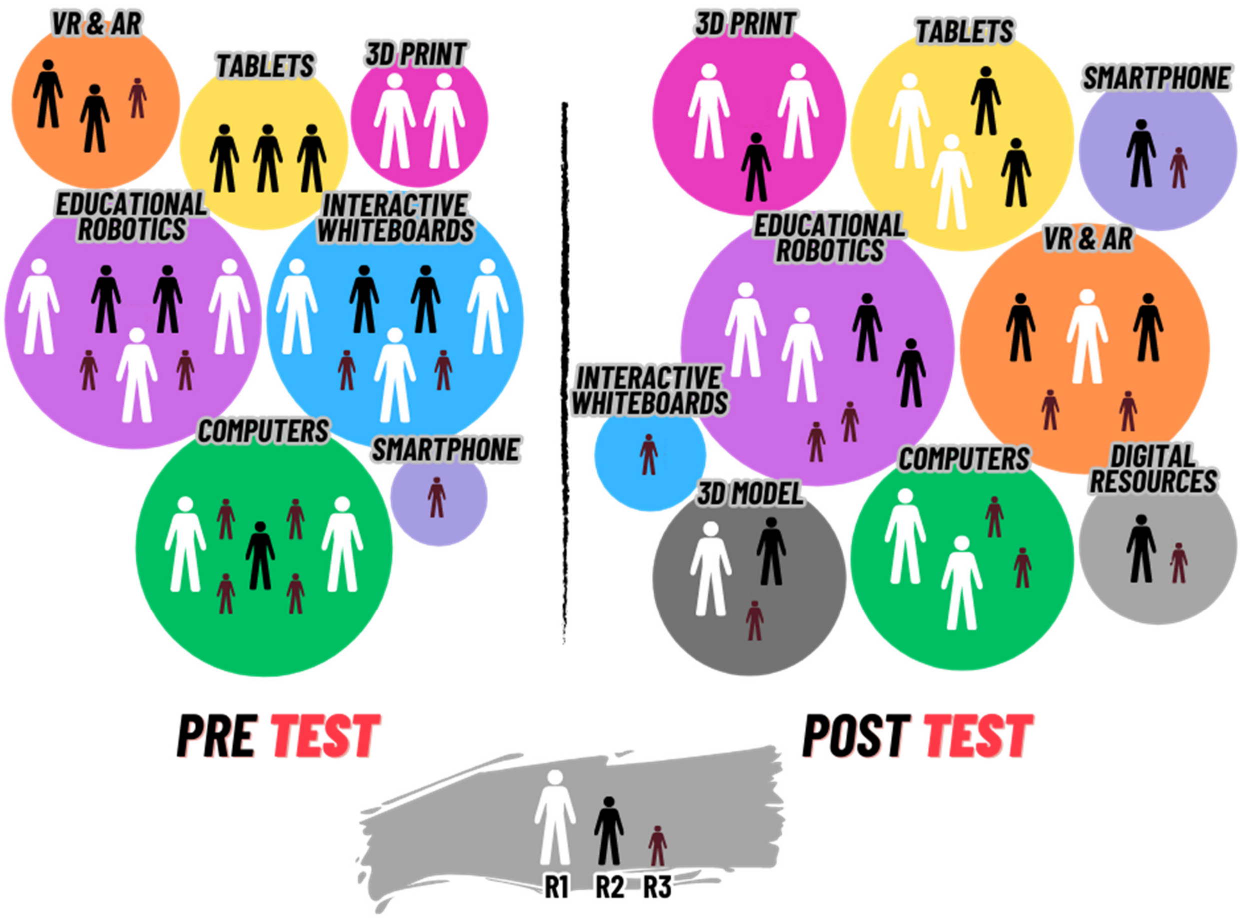

Figure 2. Qualitative results of CUTE-STEM. Note: R1 refers to the first choice, R2 to the second choice, and R3 to the third choice. Additionally, it is important to note that the size of the circle represents the degree of preference, with larger circles indicating a stronger preference.

In question 2 (the difference between immersive reality technologies), the participants in the pretest provided relatively vague responses, with some acknowledging differences related to immersion and perspective. In contrast, the posttest responses displayed a clearer understanding of the distinctions. The participants noted that virtual immersive reality allows individuals to become part of the experience, while augmented reality involves viewing objects or scenes in a 3D context. This evolution in understanding indicates the impact of the training in refining their knowledge of emerging technologies.

About question 3 (advantages or disadvantages of VR), the pretest responses were mixed, with mentions of advantages, such as enhanced engagement, and disadvantages, like the need for specialized training and cost concerns. The posttest responses highlighted several advantages, including enhanced learning experiences, the ability to create custom educational scenarios, and increased student engagement. Disadvantages were also noted, such as the need for substantial investments in technology and training.

Regarding question 4 (additional observations), in both the pretest and posttest, there were references to the importance of teacher training and staying updated on emerging technologies. Some of the participants expressed the need for ongoing, in-depth workshops rather than short courses. Additionally, the posttest responses emphasized the enjoyment and practicality of hands-on activities involving emerging technologies.

The qualitative results indicate a positive shift in the participants' understanding of attitudes toward emerging technologies in STEM education. The IVET&STEM course appeared to enhance their awareness of the potential benefits and challenges associated with these technologies. This aligns with the quantitative findings, emphasizing the importance of comprehensive teacher training in digital competencies to bridge the gap between technology and education effectively.

3.3. Qualitative Results: Thematic Analysis of Semi-Structured Interviews with Participants

This section presents the thematic analysis results from the semi-structured interviews where three themes related to technology integration in STEM education at the primary level have been identified (Table 5).

Table 5. Thematic categories and descriptions for semi-structured interviews.

Categories	Definition
(a) Perceptions of Technology in Contemporary Society	This category explores participants' general perceptions of technology in today's society. It encompasses their views on the abundance of information, the role of technology in education, and the need for responsible technology usage to avoid misinformation.
(b) Experiences and Opinions on Emerging Technologies in the Course	This category centers on participants' experiences with specific emerging technologies, such as Virtual Reality, 3D Printing, and Robotics, during the course. It includes their opinions on the potential benefits and challenges associated with the implementation of these technologies in educational settings.
(c) The Relationship Between Technology and Teaching Methodologies	This category focuses on the participants' perspectives regarding the integration of technology with teaching methodologies. It includes discussions on the need to move away from traditional passive teaching approaches and the importance of adopting more active, student-centered methods. Additionally, it addresses the potential of technology to enhance the learning process when appropriately aligned with educational objectives.

Regarding the first category of analysis (Perceptions of Technology in Contemporary Society), the participants indicated their perceptions of the use of technology in contemporary society. P09 highlighted the importance of adapting to technological advancements, stating that "*Technology improves the quality of life and is indispensable; we need to embrace it*". This positive outlook emphasizes the potential benefits of technology in enhancing daily living. On the other hand, P07 shared concerns about information overload and the need for responsible technology usage, mentioning that "*There's so much information available, and we must teach students to discern reliable sources*". This cautious perspective acknowledges the challenges associated with the abundance of information in the digital age. Additionally, P02 emphasized the role of technology in the art field, stating that "*Digital art and 3D technologies are vital in the contemporary art world, bridging ephemeral and material aspects*". This perspective highlights the transformative role of technology in the arts, bridging traditional and digital mediums.

The second category of analysis (Experiences and Opinions on Emerging Technologies in the Course) shows that the participants shared their encounters with emerging technologies throughout the course, expressing a sense of optimism and acknowledging the potential benefits. P07 expressed excitement about virtual reality (VR) in education, stating that "*VR can take students to places they've never been, enhancing their learning experience*". This enthusiastic view emphasizes the immersive and engaging nature of VR technology in education. P09 mentioned the challenges of integrating technology into the curriculum, saying that "*Adapting technology to the curriculum requires collaboration and time from teachers*". This observation acknowledges the practical considerations and collaboration needed for successful technology integration. P03 discussed the potential of robotics, noting that "*Robotics in education goes beyond programming; it can teach teamwork and problem-solving skills.*" This positive perspective underscores the multifaceted benefits of robotics education beyond coding, fostering essential skills for students.

The third category (Relationship Between Technology and Teaching Methodologies) shows that the participants discussed the integration of technology with teaching methodologies, emphasizing student-centered and innovative approaches. P07 advocated for student-centered approaches, expressing that "*Technology should empower students to take an active role in their learning process*". This view emphasizes technology as a tool for empowering students to become active participants in their education. P09 highlighted the significance of project-based learning, stating that "*STEM learning is best achieved through project-based approaches*". This positive perception underscores the effectiveness of project-based methods in STEM education, fostering practical skills and real-world application. P02 discussed the value of blending technology with art education, saying that "*Combining digital art with traditional techniques can enhance artistic expression*". This perspective acknowledges technology's role in enhancing artistic expression through the integration of digital and traditional artistic techniques.

Overall, the participants' perceptions of technology were characterized by a balance of optimism and caution, recognizing the potential benefits while acknowledging the challenges. They expressed enthusiasm for emerging technologies such as virtual reality and robotics, recognizing their transformative potential in education. Furthermore, they emphasized the need for student-centered and project-based teaching methodologies, such as STEM or STEAM approaches, to effectively integrate technology into the learning process, fostering a dynamic and engaging educational experience.

4. Discussion

These findings reinforce the pressing need to develop technology-centric educational programs, particularly for future educators. This need is precipitated by the immediate challenge of mediating between the learning–teaching process and increasing technological advancement. Frequently, teachers find themselves lacking the necessary competencies or sufficient training to effectively employ technologies in classroom settings. This discord between the escalating demand for technology in education and teacher readiness has long been a subject of discussion and concern [18,34,35,47]. The positive qualitative feedback from the students underscores the course's successful development, underscoring the necessity of similar initiatives in initial teacher training. This positive feedback from the educators signifies a potential demand for more such specialized courses that promote technology integration [15,40,41].

The quantitative results of the application of CUTE-STEM provide a more in-depth understanding of the students' perceptions and attitudes in relation to the evaluated dimensions. In dimension A, "Attitude towards technology in education", the quantitative results show a significant variation, reflecting the students' overall positive perception. This variation is corroborated by their qualitative responses expressing a strong enthusiasm for implementing technology in the classroom. Other studies have emphasized the importance for teachers to develop the ability to design and create innovative technological resources in order to enrich and enhance their educational activities [37,39,47].

About the "Frequency of use of Augmented and Virtual Reality for entertainment and educational purposes" (dimension B of CUTE-STEM), a notably positive appreciation is observed. The quantitative results indicate that students recognize the importance of familiarizing themselves with emerging technologies. The qualitative responses of the interviews reinforced this finding, with the students mentioning how exposure to emerging technologies during the course improved their confidence and skills in using these tools. This shift in preference is significant, with students emphasizing the value of hands-on application over mere theoretical knowledge of technology. In this regard, the importance of teachers familiarizing themselves with technology as a fundamental requirement in their training for effective integration is underscored [17,18,22,48].

In relation to dimension C of CUTE-STEM ("Feasibility of using Technologies for STEM Learning in Primary Education"), the quantitative findings indicated generally positive attitudes, a situation that is reflected in the responses of the qualitative section. The students' quantitative responses suggested a recognition of the feasibility of incorporating emerging technologies in primary education, while the qualitative data highlighted the perceived potential of these technologies in enhancing STEM education. This was especially observed with immersive virtual reality. While the students did not express significant differences between the pre- and post-assessments regarding the ease of use of this particular technology (item 15), there was a high valuation of the potential they attribute to it, even with moderate positive variations concerning its potential in the posttest (item 21). Nevertheless, practical implementation of VR technology in classrooms will require appropriate teacher training and reliable technological infrastructure [49,50].

Regarding dimension D of CUTE-STEM, "Potential of Technologies as a Resource for STEM Learning in Primary Education", the students agree on technology's transformative potential in STEM learning. This aligns with the STEM approach that promotes students' active participation and integrates disciplines through project-based learning, enhancing academic and social skills [3–6,51]. Real-world problem-solving tasks further enrich the learning environment [22,36,37]. However, the practical application of these approaches still poses a significant challenge, underscoring the need to enhance teachers' technological competence [35,39,48].

5. Conclusions, Limitations, and Prospective

The need for a complementary training proposal for teachers in initial training that incorporates the use of emerging technologies as resources for STEM teaching is evident (SO1). The participants' responses indicate a positive attitude toward technology in education, and they recognize its potential to enhance the teaching and learning process. However, it is equally clear that teachers require comprehensive training to effectively integrate these technologies into their pedagogical practices.

This study highlights the gap between the perceived potential of emerging technologies and their practical use in the classroom. The training program should not only introduce these technologies but also provide hands-on experience and guidance on their effective utilization (SO2).

The participants' opinions, as characterized through this research, emphasize the importance of integrating emerging technologies for STEM education. While there is enthusiasm and recognition of the benefits, there is also a realization of the challenges, particularly in terms of the ease of use and implementation (SO3).

In conclusion, the study's findings reinforce the significance of technology-centric education, especially for future educators. It underscores the need for targeted training programs that bridge the gap between technological potential and practical classroom application. Integrating emerging technologies aligns with contemporary pedagogical approaches, such as STEM education, supporting active student participation and problem-solving skills. To fully harness the potential of emerging technologies, it is essential to provide educators with the necessary training and support.

Additionally, the high perceived potential in emerging technologies, with immersive virtual reality being a notable case, contrasts with the ease of use attributed to it. The development of training pathways that include the use and manipulation of these technologies could contribute to narrowing the gap between the technology and its effective inclusion as a resource for learning.

It is important to note that the quantitative results of this study are limited by the small number of participants.

Future studies could examine STEM teacher training needs in different educational contexts, explore efficient strategies for tech integration training, and assess its impact on student outcomes. This work also invites further investigation into the role of institutional support in technology integration, ultimately aiming to enhance teaching and learning in the digital age.

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