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Cognitive and Emotional Development of STEM Skills in Primary School Teacher Training through Practical Work

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Abstract: Several studies highlight that trainee primary school teachers show negative emotions towards learning and teaching STEM subjects with low levels of teacher self-efficacy in these areas. The general objective of this research was to analyse the cognitive, emotional and didactic development of STEM competences in trainee primary school teachers. Practical STEM experiences were designed and implemented to promote a positive evolution in the cognitive, affective and self-efficacy domains of future primary school teachers. A quasi-experimental research design was followed with a control group, experimental group, pre-test and post-test. The teaching methodology used was considered as the independent variable and the level of knowledge, the level of teaching self-efficacy and the emotions experienced when learning and teaching STEM content were considered as dependent variables. A non-probabilistic sample of 345 trainee primary school teachers took part in the study. The results led to the development of more than 70 STEM workshops. The inferential statistical analysis revealed the existence of statistically significant differences in all the variables of the study, detecting a positive evolution of the trainee teachers at a didactic, competence and emotional level. It is concluded that the use of practical STEM activities may lead to an improvement in the professional development of teachers and in the quality of science and technology teaching.

Keywords: STEM education; teachers in training; primary education; emotions; teacher self-efficacy

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1. Introduction

Science and technology applications have an important place in our daily lives because they provide economic and industrial developments in many countries around the world. However, improvements in science and technology depend on the scientific knowledge, skills and attitudes that are adopted as a way of life [1]. Although there are many reasons why scientific literacy is useful, it is striking how little scientific training there is in a society that claims to value and admire scientific and technological advances [2]. Ignorance of science, of its usefulness and of the limitations and demands of scientific truth, can be seen in many day-to-day situations, in the superficiality with which scientific topics are treated in general and in the social acceptance that some beliefs or pseudo-sciences have today [2].

Some people accept as normal the fact that scientific knowledge is only available to highly skilled minorities. However, science has determined relevant issues such as current sustainable trends, countless advances in the health sector or multiple improvements in the educational and administrative context. In this sense, having an adequate vision of the problems facing humanity today, their causes and possible measures that can be taken, facilitates decision-making [3]. For this reason, the preparation of a responsible citizenry capable of making decisions in a global and complex world is a fundamental objective in the educational framework.

Today, true learning requires being able to use science and technology. Not only to improve the ability to memorise and repeat facts, but to transform information into knowledge that can solve real problems and innovate effective ideas that have applicability [4,5]. Scientific and technological literacy is necessary to help develop citizens and future scientists who can function in today's world and who are aware of the important role that science and technology play in their personal and professional lives and in our society. Therefore, scientific and technological literacy is one of the most important skills and should be reinforced from an early age at school. Consequently, the numerous scientific-technological advances of the last decade have driven many institutions to promote training programmes that enhance the scientific literacy of our current population [6,7]. In this way, they contribute with adequate knowledge to solve the problems required by current and future society [8].

Despite the importance of encouraging study and interest in scientific fields, students' experiences of science-related classes are often negative due to transmissive didactic models and the explanation of decontextualised content [9]. According to some authors, over the last decades there has been an abuse of a positivist orientation in science teaching [10]. This academicist approach based on the transmission of content has excluded the affective domain of students from the teaching process, considering it inappropriate and non-scientific [11]. This has led to the development of undesirable attitudes towards science [12]. In fact, negative emotions towards science learning are manifested in students at different educational stages [11,12]. However, some authors point out that this rejection of science becomes stronger as the age of the student increases [13–15].

Against this background, a new educational paradigm called STEM (Science, Technology, Engineering and Mathematics) education has gained popularity in recent years. STEM education [16,17] is understood as the integrated academic approach to all areas of science and technology. STEM learning environments refer specifically to classrooms or schools where conscious and open efforts are made to coordinate the learning objectives and learning activities of all STEM disciplines [18]. In this sense, integration is an essential characteristic of a learning environment if it is to be called STEM [19]. The principles describing STEM education integrate all disciplines, specifically through engineering activities as described by some authors [19], and are extremely promising.

This interdisciplinary integration aims to increase the possibilities for social development and improve the employability options and conditions of young people and thus enhance professional vocations in STEM [20–23]. Against this backdrop, the promotion of STEM education has taken centre stage in educational planning policies. Many programmes focusing on STEM skills have been launched around the world, mainly in response to political and business calls [24]. These environments are increasingly seen as complementary to school-based learning [25]. According to some studies [26], participating in STEM programmes also fosters the development of a stronger self-concept related to STEM areas, which may increase the chances of students showing greater interest in these scientific-technological areas [27]. In addition, several studies [28,29] have found that students who learn through an integrated STEM curriculum perform as well as or better than students who receive traditional, separate STEM instruction. These studies find that integrated lessons can help students connect learning across disciplines and to the real world. Other studies [30–34] have analysed the impact of a hands-on, project-based STEM curriculum on the academic achievement of primary and secondary school students in STEM areas. For example, the results of some of these studies report that students who participated in the programme achieved higher academic achievement in mathematics [30], a higher probability of pursuing these subjects in secondary education [31], and a higher probability of enroling in a STEM major at university [32]. In addition, other authors [33,34] conclude that hands-on STEM programmes offer an approach to motivate and prepare students for STEM education.

To integrate science and technology areas as a resource to promote students' scientific literacy, factors such as the teacher profile must be taken into consideration. The successful implementation of STEM education programmes may depend on teachers' self-efficacy beliefs [24,35]. That is, their personal beliefs regarding their ability to teach science greatly influence students' academic outcomes [36,37]. In general, trainee teachers often display negative attitudes and emotions towards teaching and learning STEM subjects [14]. This is especially true for primary school teachers, who often lack knowledge about the content of different STEM subject areas, which makes them feel insecure and not competent [24,36,38]. Thus, some studies [39] indicate that self-efficacy beliefs motivate the subjects to perform tasks in which they feel competent and confident, determine how much effort and time the student will require to complete the task, and greatly influence the choices that are made and the behaviours that are performed to follow them. However, research on teacher self-efficacy indicates that trainee teachers at the primary school level frequently experience negative emotions and low levels of teaching competence when teaching science and technology subjects, especially in physics [40]. Research has shown that many trainee teachers have a poor background in science content [41,42] and that many had bad experiences as science students and, as a result, show negative attitudes towards science [43,44]. These factors can lead to a lack of confidence when it comes to teaching science [45] and lead to poor science teaching at school [46]. Some authors [38] suggest that trainee teachers need to adopt both science content knowledge and personal experience of teaching and reflection to become confident practitioners. The lack of confidence can be partly attributed to a lack of experience with authentic teaching experiences. In this sense, it has been shown that effective teaching practices can help overcome the science literacy gap and improve primary school teachers' confidence and effectiveness in teaching science [47].

In light of the above, the training of future pre-primary and primary school teachers is a fundamental matter for the entire education system [48]. Therefore, initial teacher education should be framed in academic programmes based on the development of competences that promote interdisciplinarity, as well as the integration of knowledge and its appropriate assessment [49]. Numerous studies confirm the positive impact of integrated STEM education on the content knowledge and pedagogical content knowledge of prospective teachers. For example, in some studies [50], teachers attended an eight-hour STEM in-service training workshop in which they built toys to address physics topics (forces, sound, thermodynamics, electricity, etc.) with primary school students. The results of the study [50] revealed that the participation of future teachers in this type of activity promoted their learning and motivation for science lessons. Other authors [51] described research in which 119 trainee teachers developed a lesson plan that included an interdisciplinary STEM approach as part of a course they were attending. The results showed significant improvements for the trainee teachers in relation to their perceived ability to create materials for STEM education, confidence and commitment to develop such lessons in their future practice, and awareness of the potential of content integration to help students learn in a more interesting and meaningful way.

Teachers are generally supportive of students' development of STEM knowledge and skills and show great interest and motivation to learn about this paradigm [52]. However, while recognising the importance of introducing STEM education in education, teachers tend to be rather hesitant about its use in the classroom [14]. Nevertheless, teaching is a profession that requires full commitment and constant innovation to ensure meaningful learning acquisition for students [53]. Effective planning of learning activities that integrate diverse content requires teachers to have well-developed subject knowledge and pedagogical content knowledge in one or more of the STEM disciplines [54]. In addition, teachers, as educators and trainers, need to reflect on their pedagogical practice to improve and strengthen it, and from there, develop new knowledge and skills when confronted with particular classroom situations [55].

On this above described basis, the task of teacher training implies recognising the structuring of an own thinking based on the social sphere. This is not limited to passively reproducing the pedagogical proposals of various authors but focuses on understanding them from the conceptual structure in which they are formulated [56]. Didactic planning is a tool that teachers can use to make their actions effective. By planning the strategies, techniques and support resources in the classroom to achieve the objectives, the teacher will achieve a high sense of self-efficacy [57]. From this point of view, the teaching methodology to be applied according to major experts [58] is enquiry or educational research as opposed to the mere transmission of knowledge. These teaching strategies centred on the students and their learning process also require greater participation and active involvement of teachers. Teachers must change their roles from teaching what they know to helping students learn, working in teams and collaborating with other teachers [59]. It is necessary for teachers to design learning strategies that enable students to acquire confidence and competence to perform activities that are conducive to the acquisition of learning [60]. However, it is also imperative that teachers receive continuous training in such strategies for them to acquire comprehensive professional development aimed at fostering experiential, contextual, meaningful and exciting learning in their students, thus preventing attitudinal decline towards these subjects and alleviating the lack of STEM vocations from the early school stages [20,61]. If trainee teachers gain confidence and show positive attitudes, they will be better at teaching science and technology and will be able to improve the quality of teaching [62,63].

Based on the above-mentioned antecedents related to the low initial levels of knowledge and teaching self-efficacy [64,65], as well as the negative emotions of primary education teachers in training in scientific areas [14,35], the purpose of the research presented here was to analyse the influence of carrying out STEM projects on these variables. Specifically, the aim was to promote an improvement in the didactic, cognitive competence and affective component of the future primary school teacher with didactic strategies that integrate interdisciplinary learning of science and technology through practical workshops, and that are applicable to the primary school classroom.

2. Materials and Methods

The research design followed a quasi-experimental design, with control group, experimental group, pre-test and post-test. For the quantitative comparative analysis between groups, the teaching methodology used in the control and experimental groups was considered as an independent variable. As dependent variables, the level of knowledge, the level of teaching self-efficacy and the emotions experienced when learning and teaching STEM content in a sample of primary school teachers in training were used.

2.1. Objectives

The general objective of the research was to analyse the cognitive, emotional and didactic development of STEM competences in trainee primary school teachers. Specifically, practical STEM experiences were designed and implemented to promote a positive evolution in the cognitive domain, affective domain and teaching self-efficacy of trainee teachers. The aim was to foster positive emotions in future teachers, as well as cognitive and didactic skills in relation to the scientific-technological and mathematical subjects they will teach to their future primary school students (10–12 years old). To achieve this objective, several specific objectives were formulated:

Specific Objective 1: To develop practical STEM activities that are easy to implement in primary schools (10–12 years old), with the aim of contributing to fostering scientific-technological and mathematical vocations in the future from the earliest educational levels.
Specific Objective 2: To compare the evolution of the variable level of knowledge of primary school teacher trainees after the development of two didactic interventions.
Specific Objective 3: To compare the level of teacher self-efficacy shown by the participant sample before and after the didactic interventions implemented.
Specific Objective 4: To diagnose and analyse the emotions experienced by trainee primary school teachers in STEM areas, before and after the implemented teaching interventions.
Specific Objective 5: To find out the reflections and opinions of future primary school teachers towards the development of practical STEM activities in the classroom.

2.2. Hypothesis

Based on the objectives formulated in this research, the following hypotheses were formulated regarding the variables under study:

Concerning the variable level of knowledge and related to the Specific Objectives 1 and 2:

Hypothesis 1 (H1). *The implementation of practical STEM activities significantly favours the learning of scientific-technological and mathematical contents of the future primary education teacher, finding statistically significant differences between the control group and the experimental group.*

Concerning the variable level of teaching self-efficacy and related to Specific Objective 3:

Hypothesis 2 (H2). *The level of teacher self-efficacy improves significantly after the implemented didactic intervention based on the development of practical STEM activities.*

Concerning the variable emotions and related to the Specific Objective 4:

Hypothesis 3 (H3). *There are statistically significant differences between the emotional variables measured before and after the didactic interventions implemented.*

Concerning the opinions of the participant sample and related to Specific Objective 5:

Hypothesis 4 (H4). *The participating sample considers the development of practical STEM activities in the classroom to be useful for their training as future primary school teachers.*

2.3. Sample

The participating sample was selected by means of non-probabilistic convenience sampling due to the ease of access to it. Specifically, 345 future teachers of Primary Education, who were in their final year of their degree at the Faculty of Education, participated in the study. The participants were aged between 21–30 years old. Most of the participants, around 80%, come from a social sciences or humanities baccalaureate, so their initial scientific-technological and mathematical knowledge is usually limited. This sample was divided into several homogeneous working groups, equivalent in terms of initial knowledge level, which acted as control groups (CG) or experimental groups (EG) depending on the teaching strategies used. Both the control group and the experimental group used the same amount of time to teach the contents worked on during the study. Table 1 shows the descriptive analysis of the sample according to group and gender.

Table 1. Descriptive analysis of the sample according to group and gender.

Degree	Group	Gender	Percentage	Frequency	Total
Degree in Primary Education	Control (CG)	Male	30.43%	35	115
		Female	69.57%	80	
	Experimental 1 (EG1)	Male	26.73%	27	101
		Female	73.27%	74	
	Experimental 2 (EG2)	Male	29.46%	38	129
		Female	70.54%	91	

As shown in Table 1, the Control Group (CG) consisted of 115 subjects. A traditional didactic methodology was used with this group, based on an expository didactic model centred on the student. Presentations, theoretical explanations, exercise resolution and traditional laboratory practices related to the concepts under study were used as learning resources.

On the other hand, the two experimental groups consisted of a total of 230 subjects. As shown in Table 1, 101 subjects participated in Experimental Group 1 (EG1) and 129 in Experimental Group 2 (EG2). A more active methodology was used with the experimental groups, focusing on the design and development of practical projects using easy-to-acquire materials that integrate STEM contents.

These projects had a dual purpose. On the one hand, in their role as future teachers, to improve their teaching competence in STEM areas. On the other hand, in their role as undergraduate students, to improve their own level of knowledge and emotional responses to STEM areas [34,61,66,67]. These projects were carried out from a didactic approach, explaining the selected science, technology, engineering and mathematics contents to the students in an interrelated way. Specifically, the students in the experimental groups had to design, elaborate and present a technical project in subgroups of 3 or 4 components under the approach of an integrated STEM education.

The project was to be aimed at future primary school pupils (10–12 years old) to promote scientific literacy and STEM vocations in this age group. A working guide was provided specifying the minimum criteria for the development of the project. The main idea was to integrate content from the four disciplines that make up STEM education (Science, Technology, Engineering and Mathematics). The contents had to be contextualised in the current education curriculum. To this end, the groups selected the content, evaluation criteria and curricular learning standards that formed part of the STEM project they were going to develop, and specified the relationship of this with the key competences and with the transversal elements included in the primary education curriculum.

Subsequently, they had to prepare a didactic guide specifying the didactic and methodological components of each project and detailing the formal explanation of the STEM contents involved in the workshop, as well as the materials and the necessary procedure for its implementation, among other sections. Likewise, the participating sample had to prepare an observation sheet that included procedural questions related to the main contents of the project so that the students for whom the workshop was designed could solve them before, during and after the practical workshop. The aim of the questions included in the observation sheet was to focus the students' attention on those aspects of interest in the project that were key to the learning of the contents worked on.

During the workshop, the students had to build a technological object that would allow them to work with the selected STEM contents. Regarding the materials with which the prototype was to be built, it was emphasised that these had to be easy to acquire or recycled, to facilitate its reproduction in the classroom of the different schools, both in formal and informal learning environments. Additionally, the future primary school teachers had to make a video tutorial showing the construction of the technological object step by step, with the aim of integrating it into flipped classroom methodologies in the primary school classroom. In this way, the construction of the technological object could be facilitated prior to the teaching activity in the classroom. By way of example, Figure 1 shows some of the technological objects constructed by the students.

2.4. Measuring Instrument

To analyse the variables under study (cognitive, emotional and teacher self-efficacy), several valid and reliable measurement instruments were designed based on previous research [14,34]. Specifically, a pre-test and a post-test were designed and implemented before and after the didactic intervention based on the development of STEM workshops to assess the cognitive, emotional and competence evolution of the sample.

The pre-test consisted of 3 parts and was implemented before the didactic intervention. The first part contained 20 questions referring to the variable level of knowledge. The questions were multiple-choice and were formulated to detect possible misconceptions of the participant sample about the selected contents. The second part of the pre-test included 27 statements to assess the level of teaching self-efficacy regarding the scientific-technological contents that the future primary school teachers must explain to their future students. These statements were taken from the current primary education curriculum of our region. This section was measured on a Likert scale of 0 to 4 points, where 0 was "Not at all competent", 1 was "Not very competent", 2 "Somewhat competent", 3 "Fairly competent" and 4 "Fully competent". The third part of the pre-test aimed to analyse the emotions expressed by the participant sample towards STEM areas. Based on previous studies and according to the taxonomy of emotion classification [14,68,69], ten emotions were selected, five were positive (joy, confidence, fun, interest and calm) and five were negative (insecurity, boredom, stress, anxiety and worry). The participant sample had to choose the degree of manifestation of these emotions using a Likert scale from 0 to 3 points (0: I never feel it, 1: I sometimes feel it, 2: I feel it quite often, 3: I always feel it).

Figure 1. Example of technological objects built by the students in the experimental groups.

In addition, as a post-test, a questionnaire was prepared with a section to assess the level of knowledge consisting of ten multiple-choice questions like the pre-test and five open-ended questions. Likewise, the statements on self-efficacy from the pre-test were included, as well as positive and negative emotions, following the same assessment criteria. Finally, this questionnaire contained a meta-cognitive work diary with the aim of assessing the participants' own cognitive, didactic and competitive evolution, as well as the usefulness of the STEM workshops for learning and promoting scientific literacy in their role as both primary school students and future primary school teachers. Table 2 shows, by way of example, some of the questions from the knowledge tests and Table 3 shows some of the items for assessing the level of teaching self-efficacy.

Table 2. Examples of questions included in the knowledge tests.

Question	Options
Two spotlights are used to illuminate a stage. One is fitted with a cyan filter and the other with a green filter. What colour does the stage appear to be illuminated?	(a) Red (b) Blue (c) Yellow (d) White (e) Black (f) Green (g) None of the above, it would be . . . (write the option that you consider)
The force weight:	(a) Its modulus is less than the mass of the object (b) Always coincides with the mass of the object (c) It always coincides with the modulus of the normal force if the supporting surface is horizontal (d) In the IS, its unit of measurement is the Newton (e) None of the above is correct
Of the following statements, which one(s) is/are false?	(a) The existence of forces acting on an object implies movement (b) The resultant force on a body is proportional to the acceleration of the body (c) If a body is at rest on a surface, then its weight must be zero, as must the normal (d) The existence of forces acting on an object implies rest (e) The static friction coefficient is always higher than the dynamic friction coefficient
What pressure does a body with a mass of 100 kg exert on a supporting surface if its area is 100 cm^2?	(a) 10 N/cm^2 (b) 1 N/cm^2 (c) 100,000 N/m^2 (d) None of the above, it would be . . .
A cardboard box weighing 250 g is standing on a horizontal floor, then . . .	(a) The dynamic frictional force of the box on the ground is small, so it does not move (b) The ground exerts a force on the box that is greater than the weight of the box, so it does not move (c) The weight of the box is 2.5 N (d) The forces on the box cancel each other out, so it does not move (e) None of the above is correct

2.5. Validation of the Evaluation Instrument: Calibration Indexes

Results are presented on the validity and reliability of the test used to measure the level of knowledge. For this purpose, an analysis similar to that recommended in other research [70–72] was carried out. Initially, a test of concordance between experts was carried out. The questionnaire was reviewed by expert teachers in didactics of experimental sciences to check whether the questions included in the questionnaires were adapted to the level of the participating subjects or whether their wording was appropriate for the achievement of the objectives. The data provided by the group of experts indicate that the questionnaire was favourable for the research, obtaining a value higher than 0.9, which can be classified as very good according to the literature [70]. On the other hand, several psychometric tests focused on the assessment of the test items were carried out, such as the difficulty index, discrimination indices, point biserial coefficient, Ferguson's Delta, and

KR-20, using the methodologies specified in previous studies. As can be seen in Table 4, all values are within the recommended range.

Table 3. Example of items for assessing teaching self-efficacy.

I Feel Qualified to . . .	Assessment (From 0 to 4)
Identify, describe and classify some materials by their properties (hardness, solubility, state of aggregation, thermal conductivity, etc.).	
Know the procedures for measuring the mass, volume and density of a body.	
Use different procedures for measuring the mass and volume of a body.	
Identify and explain the main characteristics of buoyancy in a liquid medium.	
To know basic laws governing phenomena such as change of state, chemical reactions, combustion, oxidation and fermentation.	
Plan and carry out simple experiments and predict changes in the movement, shape or state of bodies due to the effect of forces or energy inputs, communicating the process followed and the result obtained.	
Identify and explain some of the main characteristics of the different forms of energy: mechanical, light, sound, electrical, thermal, chemical.	
Identify and explain some of the main characteristics of renewable and non-renewable energies, identifying the different energy sources and raw materials and the origin from which they are derived.	
Identify and explain the benefits and risks related to the use of energy: depletion, acid rain, radioactivity and outlining possible actions for sustainable development.	
Knowing and stating the basic principles governing machines.	
Identify different types of machines.	
Classify machines according to the number of parts, the way they are operated and the action they perform.	
Identify and describe some of the components of the machines.	
Identify some of the applications of machines and devices and their usefulness in facilitating human activities.	
Plan the construction of objects and devices for a given purpose, using appropriate energy sources, operators and materials.	
Perform individual and teamwork and provide feedback on what strategies have been employed.	
Build a simple structure that fulfils a function or condition to solve a problem from modular parts (stairs, bridge, slide, etc.).	
Explain and state the basic laws governing phenomena such as the reflection of light, refraction of light, etc.	
Explain and state the basic laws governing phenomena such as the transmission of electric current.	
Identify the elements of an electrical circuit and build one.	
Identify and explain some effects of electricity.	
Give examples of conductive and insulating materials.	
Identify the main characteristics of magnets and relate electricity and magnetism.	
Know and explain some of the great discoveries and inventions of mankind.	
Carry out simple experiments and small research on different physical phenomena of matter: posing problems, stating hypotheses.	
Carry out simple experiments and small research on different physical phenomena by selecting the necessary material, assembling, carrying out and drawing conclusions.	

Table 4. Psychometric analysis of the Evaluation Instrument.

Coefficient	Obtained Value Pre-Test	Obtained Value Post-Test	Recommended Value
Mean difficulty index (P)	0.35	0.69	[0.30–0.90]
Mean discrimination index 1 (D1)	0.34	0.44	$\geq$0.30
Mean discrimination index 2 (D2)	0.79	0.67	$\geq$0.50
Mean point biserial coefficient (r_{pb})	0.27	0.31	$\geq$0.20
Ferguson's Delta (δ)	0.97	0.96	$\geq$0.90
KR-20	0.74	0.79	$\geq$0.60

It can be seen in Table 4 that in the pre-test, an average value of $p = 0.35$ is obtained, which indicates that the instrument for measuring the initial level of knowledge has a high difficulty for the subjects who took it. However, it is observed that in the post-test that the average value of $p = 0.69$, which indicates that the level of difficulty of the questionnaire is adequate according to the literature. This variation in the level of difficulty of the instrument applied may be due to the intervention that has improved the quality of the trainee teachers' responses in the post-test.

Additionally, discrimination indices were calculated. Discrimination Index 1 (D1) reports the discriminatory power of each item in a test to distinguish between proficient and less proficient students [73,74]. As the average value obtained in the pre-test was D1 = 0.34 and in the post-test was D1 = 0.44, it is assumed that the questions have a correct discrimination index in both cases. The Discrimination Index 2 (D2) indicates the proportion of correct answers in the group of students with the best marks in relation to the total number of correct answers. It can be considered satisfactory if it is at least above 0.50. In both instruments, this fact is fulfilled since a value of D2 = 0.79 was obtained in the pre-test and a value of D2 = 0.67 in the post-test. Both questionnaires show appropriate values for the mean point biserial coefficient (r) and Ferguson's Delta, according to the criterion established in each case. Finally, the Kuder–Richardson coefficient 20 (KR-20), which is a measure of internal consistency reliability for measures with dichotomous options, was calculated. A KR-20 value of 0.74 and 0.79 was obtained, indicating high reliability. Based on the results shown in Table 3, we can affirm that the test referring to the variable level of knowledge presents an adequate degree of reliability and validity, constituting a reliable assessment instrument, with an adequate level of difficulty and discriminatory power.

Regarding the validation of the test to measure the level of teaching self-efficacy, the reliability coefficient was calculated using Cronbach's alpha. The result obtained was $\alpha = 0.891$ for the items that comprise the questionnaire. This result allows us to conclude that the questionnaire for measuring the level of teacher self-efficacy presented an excellent reliability [75,76].

3. Results

The results obtained for each of the variables under study are presented. Firstly, the data obtained for the knowledge level variable are presented. An inferential analysis was carried out to check whether there were statistically significant differences before and after the intervention. Secondly, the results obtained for the variable level of teaching self-efficacy are presented, distinguishing between pre-test and post-test. Finally, we show the results referred to the emotional variables, as well as the opinions of the participant sample collected at the end of the whole process.

The IBM SPSS Statistics 20.0 software was used for the analysis and interpretation of the quantitative data. Two types of analysis were carried out: a descriptive-exploratory analysis and an inferential analysis. In the case of the inferential analysis, we worked with a significance level of 0.05 and specifically used the ANOVA test and Student's *t*-test after confirming the use of parametric tests. For the qualitative analysis, categories were established to analyse this information.

3.1. Results Referring to the Variable Level of Knowledge

This section presents the results obtained for the variable level of knowledge, related to the Specific Objectives 1 and 2 established in the research and the testing of the Hypothesis 1 formulated. Table 5 shows the descriptive statistics obtained in the pre-test in the two working groups: control and experimental.

Table 5. Descriptive statistics of the level of knowledge in the pre-test (Control Group vs. Experimental Group).

	n	Mean	Std. Deviation	Std. Error Mean
Control Group (CG)	115	2.85	1.93	0.180
Experimental Group 1 (EG1)	101	2.67	1.01	0.099
Experimental Group 2 (EG2)	129	2.70	1.57	0.138

As can be seen in Table 5, the trainee teachers started with a very low level of scientific-technological knowledge, as the average score obtained was 2.84 points out of 10 for the control group, 2.67 points out of 10 for experimental group 1 and 2.70 points out of 10 for experimental group 2. The analysis by question of the data obtained in this initial questionnaire indicates that the trainee teachers showed misconceptions about various basic contents of science, technology and mathematics, therefore, we agree with previous studies that there is a lack of preparation in this group in scientific-technological matters [77,78]. Consequently, when teachers lack training to teach subjects, they tend to use teaching strategies that allow them to maintain control of the flow of knowledge in the classroom, but these strategies are not adequate ways to engage students in science [79,80].

To check whether the two groups were equivalent before developing the didactic interventions, a comparative analysis was carried out using an ANOVA test. Table 6 presents the results of this test.

Table 6. ANOVA of the variable level of knowledge of the pre-test (control group vs. experiential groups).

	Sum of Squares	df	Mean Square	F	Sig.
Between groups	1.972	2	0.986	0.400	0.671
Within groups	843.936	342	2.468		
Total	845.908	344			

As can be seen in Table 6, there are no statistically significant differences (Sig. = 0.671) between the three groups, so it can be assumed that the sample used is indistinguishable and with similar initial knowledge.

Once the trainee teachers received the corresponding didactic interventions, the post-test was carried out to check whether the level of STEM knowledge improved. It should be remembered that the participants in the control groups received explanations of the contents under study under a traditional methodology based on the transmission-reception of the concepts, and the students in the experimental groups learned and worked on these concepts through the development of practical activities integrated in STEM projects. Table 7 shows the results obtained in the post-test, once the didactic interventions of the control group and the experimental groups were developed.

Table 7. Descriptive statistics of the level of knowledge in the post-test (control group vs. experimental groups).

	n	Mean	Std. Deviation	Std. Error Mean
Control Group (CG)	115	5.40	2.09	0.195
Experimental Group 1 (EG1)	101	6.57	1.77	0.176
Experimental Group 2 (EG2)	129	6.30	1.76	0.154

As can be seen in Table 7, all study groups improved their level of knowledge after the interventions. Specifically, students in experimental group 1 obtained an average score of 6.57 points out of 10, students in experimental group 2 obtained a score of 6.30 points out of 10 and students in the control group achieved an average score of 5.40 points out of

10. Although it is accepted that most students had significantly improved their scientific-technological knowledge, an inferential analysis was carried out between the average post-test scores of the control group and the experimental group to check whether there were statistically significant differences between them. The ANOVA carried out is shown in Table 8.

Table 8. ANOVA of the variable level of knowledge of the post-test (control group vs. experimental group).

	Sum of Squares	df	Mean Square	F	Sig.
Between groups	83.370	2	41.685	11.737	0.000
Within groups	1214.644	342	3.552		
Total	1298.014	344			

As can be seen in Table 8, the inferential analysis carried out to compare the post-test scores between the control and experimental groups reveals that there are statistically significant differences between these scores, with a significance of Sig. < 0.001. To analyse between which groups these differences occur, a Tukey's post-hoc test was carried out. The results are shown in Table 9.

Table 9. Tukey's post-hoc test.

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
CG	EG1	−1.169 *	0.257	0.000	−1.774	−0.564
CG	EG2	−0.895 *	0.241	0.001	−1.464	−0.326
EG1	EG2	0.273	0.250	0.519	−0.315	0.863

* The mean difference is significant at the 0.05 level.

As can be seen in Table 9, there are statistically significant differences between the scores of the control group and the experimental groups, in favour of the experimental groups, both with Experimental Group 1 and Experimental Group 2 (Sig. < 0.001). Specifically, the difference in means found between CG and EG1 is 1.17 points out of 10. Likewise, the difference in means found between CG and EG2 is 0.89 points out of 10. However, there are no statistically significant differences between the two experimental groups (Sig. = 0.519), as both obtain similar scores in the post-test. These data seem to indicate that the implementation of the STEM workshops favoured the learning of the contents under study to a greater extent. This confirms the validity of the STEM workshops in terms of improving the future teachers' level of knowledge of scientific-technological content. Therefore, we agree with other authors [81] that the development of STEM projects will not only help teachers to teach STEM through integrated approaches but will also help them to feel more comfortable teaching in this way before they enter the classroom. We also agree with previous studies that have shown that the use of STEM workshops with primary school students promotes meaningful and long-term learning of the content being taught [34,61].

Based on the above results, we can accept Hypothesis 1: The implementation of practical STEM activities significantly favours the learning of scientific-technological and mathematical contents of the future primary education teacher, finding statistically significant differences between the control group and the experimental group.

3.2. Results for the Variable Level of Teacher Self-Efficacy

Table 10 shows the descriptive statistics obtained for the variable level of teaching self-efficacy in each of the questionnaires implemented before and after the two interventions developed with the control group and with the experimental groups. Table 11 shows the inferential analysis carried out using Student's *t*-test for paired samples, to compare the evolution of the teaching self-efficacy variable in both the control group and the experimental groups once the didactic interventions had been carried out.

Table 10. Descriptive statistics on the variable teaching self-efficacy (Pre-test vs. Post-test; Control Group vs. Experimental Group).

Group	Test	Mean	Std. Deviation	Std. Error Mean
CG	Pre-test	1.46	0.41	0.03
	Post-test	2.02	0.73	0.06
EG	Pre-test	1.43	0.69	0.05
	Post-test	2.51	0.41	0.03

Table 11. Student's *t*-test for paired samples for the self-efficacy variable (Pre-test vs. Pos-test).

	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	Sig. (2-Tailed)
Group				Lower	Upper			
CG	−0.563	0.829	0.076	−0.713	−0.412	−7.408	118	0.000 *
EG	−1.084	0.601	0.042	−1.168	−1.001	−25.581	200	0.000 *

Sig. < 0.05 *.

After carrying out a descriptive analysis of the different statements that made up the teaching self-efficacy test, it was found that the participating sample mostly selected the items "Not at all competent" and "Not very competent" before the intervention. In other words, the future teachers presented low levels of teaching self-efficacy when teaching content related to STEM areas. Specifically, percentages higher than 50% are observed for the items "Not at all competent" and "Not very competent" in most of the proposed statements. For example, in the statement "Identify different types of machines and classify them according to their parts and/or the actions they perform", the statement "Explain the parts that make up an electrical circuit and their functions", the statement "Identify the main characteristics of magnets and relate electricity and magnetism", or the statement "Carry out simple experiments and small research into different physical phenomena, selecting and using the necessary material and drawing conclusions", among others. On the contrary, after the interventions developed, the teacher trainee improves his perception in relation to his own teaching self-efficacy. The percentage values indicate that the participating sample mostly selects the items "Fairly competent" and "Fully competent" for most of the statements.

The results of Table 11 reveal that there were statistically significant intra-group differences (Sig. < 0.001) between the values of teaching self-efficacy before and after the two groups of control and experimental. On this basis, we can affirm that the two work methodologies have produced an increase in the perceptions of teaching self-efficacy of the participants. However, to analyse which of the two methodologies was more effective, an inter-group comparison was carried out. Table 12 shows the results of the Student's *t*-test for independent samples.

Table 12. Student's *t*-test for independent samples for the self-efficacy variable in the pre-test and post-test (CG vs. EG).

	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference		t	df	Sig. (2-Tailed)
Test			Lower	Upper			
Pre-test (CG vs. EG)	0.029	0.069	−0.107	0.166	0.428	319	0.669
Post-test (CG vs. EG)	−0.492	0.063	−0.635	-0.367	−7.783	319	0.000 *

Sig. < 0.05 *.

As shown in Table 12, there are no statistically significant differences (Sig. = 0.669) between the pre-test results of the control group and the experimental group, which confirms that both groups were equivalent in terms of initial perceptions of teacher self-efficacy before starting the interventions. However, statistically significant differences were found between the post-tests of the control group and the experimental group (Sig. < 0.001), in favour of the experimental group. In other words, although both work methodologies produce a positive evolution in the perceptions of teaching self-efficacy of the participants, this evolution is more noticeable in the experimental group, who end up feeling more capable for the future teaching of the contents and competences worked on in the interventions developed. This result confirms once again the effectiveness of STEM education in improving not only the level of knowledge but also the beliefs and perceptions of self-efficacy in the teaching of scientific-technological and mathematical content. Based on this, it is considered that the professional development of trainee teachers should be carried out through their active participation by incorporating opportunities for reflection in their learning processes [82].

The above results allow us to accept Hypothesis 2: The level of teacher self-efficacy improves significantly after the implemented didactic intervention based on the development of practical STEM activities, as we observed an increase in teacher self-efficacy after the STEM workshops with the experimental group.

3.3. Results Referring to the Emotional Variable

This section includes the results obtained regarding the emotions experienced by the future primary school teachers before and after the intervention. These results are related to the Specific Objective 4 of the research and to the Hypothesis 3 formulated. Emotions influence decision-making and professional development and affect teaching behaviour in classroom management as well as cognitive and motivational stimulation of pupils [83]. For this reason, it was considered to carry out an emotional analysis of the future teacher when teaching STEM subjects before and after classroom work.

Table 13 shows the percentages obtained in the different items for each of the proposed emotions. It should be remembered that the emotions are evaluated using a Likert scale from 0 to 3 points (0: "I never feel it"; 1: "I sometimes feel it"; 2: "I feel it quite often"; 3: "I always feel it"). To simplify the presentation of the data, the percentages obtained in items 0 and 1 on the one hand and the percentages obtained in items 2 and 3 on the other hand are grouped together in Table 13.

Table 13. Percentages obtained in the emotional variable (Pre-test vs. Pos-test; CG vs. EG).

%	Pre-Test				Post-Test			
	GC	**GE**	**GC**	**GE**	**GC**	**GE**	**GC**	**GE**
	0 & 1	**0 & 1**	**2 & 3**	**2 & 3**	**0 & 1**	**0 & 1**	**2 & 3**	**2 & 3**
Joy	83.2	81.5	16.8	18.4	65.4	51.1	34.6	48.9
Confidence	75.5	83.6	24.5	16.3	48.7	43.6	51.3	56.3
Fun	89.0	91.1	11.0	8.4	75.2	55.7	24.8	43.7
Interest	91.3	88.4	8.7	11.6	31.3	28.4	68.7	71.6
Calm	79.9	81.6	20.1	18.4	76.1	55.3	23.9	44.8
Insecurity	29.5	30.5	70.5	67.9	63.8	93.7	36.2	6.3
Boredom	30.1	32.6	69.9	67.3	52.3	94.7	47.7	5.3
Stress	30.3	27.4	69.7	72.6	44.6	70.6	55.4	29.5
Anxiety	21.0	24.2	79.0	75.8	52.9	76.3	47.1	23.7
Worry	23.4	25.8	76.6	74.2	23.9	59.0	76.1	41.0

Table 13 reveals that the prospective teachers showed some rejection towards teaching and learning in STEM areas before the intervention. Consistently high percentages are observed for the items "I never feel it" and "I sometimes feel it" for positive emotions, both for the control group and for the experimental group. For example, the sum of these items is around 80% or 90% for the variables joy, confidence, fun, interest or calm. On the other hand, negative emotions reach high percentages in the pre-test in the items "I feel it quite often" and "I always feel it", with percentage values of around 70% in emotions such as stress, anxiety, worry or boredom, both for the control group and for the experimental group. These results constitute a serious problem because, if this situation does not improve, it is likely that these future teachers will transfer negative emotions towards the contents related to science and technology subjects to their own students [11]. These results reveal that the sample of participants showed mostly negative emotions towards STEM areas before the different teaching interventions were carried out. However, after the development of the teaching interventions developed with the control group and with the experimental group, it is observed that in both groups, there is a decrease in the manifestation of negative emotions and an increase in the manifestation of positive emotions. However, based on the data obtained, the increase in positive emotions and the decrease in negative emotions is more noticeable in the experimental group than in the control group, with significant differences between the two in favour of the experimental group. Specifically, the inferential statistical analysis of emotions after the STEM workshops revealed a statistically significant (Sig. < 0.05) increase in positive emotions and a statistically significant (Sig. < 0.05) decrease in negative emotions in the experimental group. Specifically, percentage values above 50% are found in emotions such as interest and confidence when adding the items "I feel it quite often" and "I always feel it". Likewise, percentage values of 94% are found in the emotion insecurity, 95% in the emotion boredom and 76% in the emotion *anxiety* when adding the items "I never feel it" and "I sometimes feel it".

These results led us to accept Hypothesis 3: There are statistically significant differences between the emotional variables measured before and after the didactic interventions implemented. These results are in line with other studies that conclude that experiential activity is a way to learn and motivate students [33], as the emotional variable improves when expository sessions are complemented with experiential and hands-on activities [14].

3.4. Results Regarding the Reflection of the Participants

In this section, the results referred to Specific Objective 5 and Hypothesis 4 set out in the research are shown. The participants' opinions regarding the usefulness of the STEM workshops for improving their levels of teaching self-efficacy were assessed using a Likert scale ranging from 1 "Not at all useful" to 5 "Totally useful". Regarding the usefulness of the STEM workshops conducted to improve primary school students' learning in STEM areas, 70% of the participating sample rated them as very useful. Regarding their assessment of the usefulness of the STEM workshops for improving their learning as teachers in STEM areas, 55% considered them to be very useful and 30% considered them to be *totally useful*. Likewise, regarding the usefulness of the STEM workshops to improve their didactic training in STEM areas, around 55% rated them as very useful and 40% rated them as totally useful.

Table 14 shows some of the reflections of the trainee teachers in the work diaries during the STEM workshops.

The results shown above allow us to accept Hypothesis 4 (H4): The participating sample considers the development of practical STEM activities in the classroom to be useful for their training as future primary school teachers.

Table 14. Metacognitive reflections following the STEM Workshops.

"Carrying out these workshops has helped us to see the usefulness of the interdisciplinary nature of the contents. We believe that this type of project helps us to improve the teaching of these contents in the classroom." Student 22
"The experience has really caught our attention and we liked it. Thanks to it, we have lost our fear of science teaching, which until now was a theoretical subject that produced a lot of negative emotions, which in turn limited our own learning." Student 39
"We, as future educators, need to be competent in this type of experience because it helps us to assimilate necessary concepts that we will pass on more enthusiastically to our pupils. In fact, if we do not assimilate them ourselves, we will not be able to transmit them correctly." Student 6
"We have acquired new knowledge. We have internalised it and reviewed other knowledge that we knew but had not worked on for a long time. If we had simply dealt with the subject in a theoretical way, without real examples, we would not have learnt in the same way, as it is monotonous and not motivating for the students." Student 8
"Science can be fun and interesting for our students (even if most of them are "scared" of it). If we explain it in a fun, friendly and playful way, and above all, by doing practical exercises like this one." Student 32
"We realised that we had a negative view of science. It has always been a subject that distressed us. However, with this project, we have found that while teaching it, we have learnt, in a practical way, content that is difficult to understand. It has awakened our interest and we have had fun, learning almost without realising it." Student 48

4. Discussion and Conclusions

The results obtained reveal an improvement in the initial development of the trainee teacher from three perspectives: attitudinal/emotional, competence/cognitive and didactic. Firstly, the results obtained in the level of knowledge variable reveal, initially, the cognitive deficiencies shown by future teachers in terms of scientific-technological content. We agree with other authors [78] that the disciplinary deficiencies in STEM areas of primary school teachers in training may represent important restrictions for quality teaching at the first levels of education. We also agree with those studies that point out that teachers' own alternative conceptions of the science topics to be taught may be one of the origins of students' misconceptions about these topics [84,85]. Therefore, science teaching that aims to develop students' scientific and technological competence requires teachers with initial training that integrates the scientific and didactic component of science teaching competence [86].

The results also confirm that transmissive strategies are ineffective in combating alternative ideas and promoting meaningful learning [87]. Content domain is a much-needed teaching quality to develop students' scientific and technological literacy [88]. For this reason, we consider that STEM education can be a great educational alternative to improve the cognitive proficiency in science, technology and mathematics of future teachers, since the results obtained in the study reveal an improvement in the level of knowledge of the respondents after the didactic intervention with STEM workshops, thus confirming its effectiveness in learning [67]. In conclusion, the results point to the overcoming of scientific inconsistencies on basic science content, which supports the idea that an integrative STEM approach, based on active methodologies, contributes positively to the development of content knowledge of trainee teachers at the early levels of schooling [89].

Additionally, the STEM workshops also lead to a consolidation of teachers' self-efficacy through the successful completion of the challenges proposed in the classroom sessions and the improvement of their perceptions of their professional capacities in the science classroom. Initially, it was observed that most of the teachers showed professional shortcomings when teaching different science contents and were unable to explain specific science contents through teaching methods that promote meaningful learning in their students, in line with previous research [66,67]. However, after being involved in designing and constructing a STEM workshop, the teacher trainees increased their perceived teaching self-efficacy in science, technology and mathematics. These results are consistent with previous studies that find that hands-on, playful experiences improve the knowledge levels and application skills not only of primary school students [33] but also of prospective teachers [4,90,91]. In short, we agree with previous research that when teachers are oriented towards processes of critical reconstruction of the traditional teaching model, subjecting them to a meaningful and functional contrast with knowledge and experiences more coherent with the results of educational research, more conscious, complex and evolved teaching-learning models can emerge in them, capable of sustaining innovative and truly valuable practice [92].

Regarding the emotional results, an improvement in the positive emotional variables was again observed after the didactic intervention proposed to the participants in the study. Initially, the trainee teachers expressed a feeling of rejection towards the teaching of scientific-technological content, with negative emotions such as boredom, worry and anxiety taking precedence. In this sense, we agree with the contributions of other authors [83] in that the emotions initially predicted by the subjects surveyed seem to be correlated with their own self-efficacy beliefs, which were also unfavourable in the pre-test, as was seen previously. Subsequently, the STEM intervention facilitated the change of positive and negative emotions as high levels of positive emotions such as confidence, interest or calm were found. In addition, there was a decrease in the display of negative emotions such as boredom, stress or anxiety. These findings are like those described in previous studies with prospective teachers [93] in which interventions based on experimental methodologies show an increase in positive emotions and a decrease in negative emotions. We believe that future teachers need to have experiences of learning science through research or experimentation because this will allow them to approach teaching with students with less anxiety and more confidence [86]. In other words, there needs to be coherence between the training model used with prospective teachers and the model of science teaching that is considered desirable for them to use with their primary school pupils [86].

Pedagogical belief in STEM is key to improving teachers' motivation and overcoming difficulties in the process of innovative teaching [94]. In fact, these beliefs of teachers can be changed through continuous training [95]. Considering that the attitudes and emotions of primary and secondary school students improve when expository sessions are complemented by experimental activities [14], it will be necessary to improve teacher training in active methodologies to promote not only the interest and promotion of scientific vocations in their future students but also to improve their own attitudes towards educational practice related to STEM areas. If teachers exhibit a negative appreciation of their teaching practice, their own students will have an unfavourable opinion of the teaching they receive [96]. Therefore, we need to prepare teachers both with a better understanding of the scientific content and the issues related to its didactics, thus providing future teachers with the necessary resources to develop responsible and informed citizenry in science and technology.

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