Chapter

# Implementation and Didactic Validation of STEM Experiences in Primary Education: Analysis of the Cognitive and Affective Dimension

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## Abstract

Several studies highlight the need to improve STEM competencies from an early age, where the first attitudes and vocations toward these subjects begin to be forged. This research pursued two general objectives: First, to analyze the cognitive and affective dimension of primary education students in relation to STEM content, using a sample of 801 students. Second, to implement and validate STEM experiences as didactic strategies that improve the teaching/learning of these areas in students aged 10–12, using a sample of 455 students. The design of the research was quasi-experimental with pretest, posttest, control, and experimental groups, analyzing both cognitive and affective variables. The inferential statistical analysis of the obtained data reveals that STEM education promotes a positive evolution in the students both in the learning and emotional variables, existing statistically significant differences compared to a traditional methodology.

**Keywords:** STEM, primary education, cognitive domain, affective domain

## 1. Introduction

In recent years, there has been a need to reorganize science and technology education programs based on the new paradigms of society. The reason for considering this area in particular is the growing need for professionals specialized in this type of education in the market, since the proportion of students who choose STEM (science, technology, engineering, and mathematics) areas in higher education is not enough [1–3]. Children's learning is strongly influenced by the contexts in which the teaching process takes place in schools [4]. Previous research has suggested that offering more rigorous math and science courses can foster higher level skills and confidence within these subjects [5, 6] and improve students' chances of pursuing STEM careers [7].

Paradoxically, while most students enjoy learning science at an early age [8], many lose interest in high school because mathematics and science seem irrelevant to their personal goals and they are not aware of the usefulness of this knowledge in everyday life [9]. As students progress academically, they begin to consider that science subjects are complex and boring [10]. Other authors [11] add that students show low motivation and mood in learning activities related to STEM areas. This can be linked to the methodologies and teaching strategies used in science classrooms [12]. Similarly, reports from the Organisation for Economic Cooperation and Development [1] state that young people are not able to solve scientific problems in creative and innovative ways and experience difficulties in addressing activities and challenges associated with the areas of science and technology. This may be associated with a lack of motivation for learning [13] or even with the emotions the students experience toward learning science [14]. With respect to emotional domain, it should be noted that several studies relate it both to cognitive domain and to the concept of self-efficacy presented by the students [15]. According to some authors [16], students' perception of their self-efficacy in scientific-technological subjects predicts their performance in these areas. Beliefs of academic self-efficacy shape students' school and professional aspirations [17]. That is, successful performance improves the perception of self-efficacy and the expectation of positive results, thus strengthening the interests and goals to be achieved [18, 19]. Students will show higher rates of self-efficacy if they show concentration, control, happiness, participation, and satisfaction during school work [20, 15]. However, academic and competency performance is lower as a negative view of addressing their learning process is higher [21].

Although students' interest and positive attitudes in science diminish throughout schooling [22], STEM interdisciplinary programs can provide the time and space needed to address this decline in scientific vocations and commitment [23]. Specifically, various studies [24] suggest that STEM competencies should be encouraged from an early age by using innovative teaching strategies that encourage the internalization of content so that it is maintained over the long term. In addition, it is more feasible to implement an integrated curriculum of these subjects in primary education because students spend most of their school time with their tutor teacher. Thus, an interdisciplinary and integrated treatment of STEM competencies would not negatively affect the educational process at these levels [25].

STEM education requires alternative didactic strategies to traditional teaching aimed at promoting a more valid and useful school science that involves students in improving their STEM skills [26]. Thus, for example, scientific models and theories will become relevant for students if they are given opportunities to test their usefulness and explanatory potential [27, 28]. The inclusion of STEM experiences in the curriculum at the primary education stage can improve the understanding of the youngest toward the diverse scientific-technological roles of society, as well as improve involvement, motivation, and the search for solutions to real problems by contextualizing mathematics, technology, engineering, and science contents [29].

Schools that offer STEM-focused programs have become the center of several policy initiatives and research projects [30]. Results from some studies [31] indicate that students' intention to specialize in one of the STEM areas or the likelihood that students will choose a STEM major is positively correlated with attendance at schools with STEM educational programs. Many educators believe that schools with a STEM approach will promote the preparation of well-informed citizens who have access to and appreciation of the ideas and tools of science and engineering [32]. In addition, schools that focus on science, technology, and innovation are also an enabling strategy for closing racial and gender gaps in learning opportunities in these fields [33]. In addition, these educational programs offer students the opportunity to have more information about STEM disciplines and greater academic and employment opportunities [31].

However, the challenges associated with change must be supported by management, continuous workforce development, and educational programs that focus on the specific needs of teachers in transition to a new form of teaching [34]. Teachers who do not acquire continuous training or those who do not have time to carefully develop an integrated curriculum may adopt an unstructured curriculum rather than a truly integrated approach [35]. Extracurricular STEM schools and programs must address the challenge from various sectors, not only by trying to improve actual achievement but also by helping students develop cognitive skills and greater confidence in their ability to learn and do science [9]. To help all students believe they can understand STEM areas, schools and extracurricular programs must address the challenge from various perspectives, helping students develop metacognition skills and greater confidence in their theoretical and procedural ability [36]. Based on this background, the research presented here is intended to analyze cognitive and affective aspects toward STEM areas in students aged 8–12.

## 2. Methodology

### 2.1 Research design

This research is based on two parallel studies focused on STEM education in the function of diverse variables related to cognitive, affective, and competency aspects.

Study 1 has been oriented to analyze the cognitive and affective dimensions that primary education students present toward STEM areas, following an exploratory research design with a mixed analysis of the obtained data.

Study 2 has been aimed at validating the implementation of STEM workshops in the primary education classroom, following a quasi-experimental research design with pretest, posttest, control, and experimental groups, analyzing both cognitive and affective variables.

### 2.2 Objectives

The research carried out has pursued two general objectives based on the two studies proposed:

General objective 1 (study 1): to analyze the cognitive, affective, and competency dimensions of primary school students in relation to STEM areas.

General objective 2 (study 2): to implement and validate STEM workshops as active didactic strategies that improve the teaching/learning of these areas in primary school students.

### 2.3 Hypothesis

The general objectives have served as a reference for formulating the following research hypotheses:

Hypothesis 1 (H1): elementary students have a low level of knowledge in STEM areas.

Hypothesis 2 (H2): there are differences in the level of knowledge in STEM areas of the primary students depending on the variable academic level.

Hypothesis 3 (H3): there are no statistically significant differences in the level of knowledge in STEM areas as a function of the gender variable.

Hypothesis 4 (H4): primary school students show a favorable attitude toward STEM subjects and their learning.

Hypothesis 5 (H5): elementary students have low levels of proficiency in STEM areas.
Hypothesis 6 (H6): there are no statistically significant differences in competency values with respect to the gender variable.
Hypothesis 7 (H7): the implementation of STEM workshops in the primary classroom as didactic strategies produces a cognitive and emotional evolution in the students.
Hypothesis 8 (H8): there are statistically significant differences in cognitive and affective variables between the students who use a traditional methodology and those who use a methodology based on the implementation of STEM workshops.
Hypotheses 1–6 are checked in Study 1 and hypotheses 7 and 8 in Study 2.

### 2.4 Sample

The sample was selected through a random process, involving 1256 primary school students. Since the two general objectives were set according to the two studies, the sample participating in the research was divided into two subsamples.

Subsample 1 consisted of 801 pupils aged between 8 and 12 from different schools. This group was used for Study 1 with an exploratory character on cognitive, affective, and competence variables.

Subsample 2 consisted of 455 students aged 10–12 from different schools. The students in each school were divided into two homogeneous groups, control and experimental according to the theme of the different STEM workshops implemented. This group was used for Study 2 with a quasi-experimental purpose to validate the didactic relevance of the implementation of the STEM workshops. The STEM contents worked on in the control groups and experimental groups have been the same and were selected from the education curriculum. The control groups (CG) have followed a methodology based on a more traditional teaching of the selected STEM contents, using as resources the textbooks and their specific worksheets. However, the experimental groups (EG) have followed a teaching methodology based on STEM workshops. This type of resources allows interdisciplinary work on diverse scientific, technological, and mathematical contents, as indicated in previous studies [37]. The workshops have been designed in such a way that they can be carried out in 2 or 3 classroom sessions. They consist of making a model with easily acquired or recycled materials to facilitate their reproduction in informal contexts. The construction of the model makes it possible to work on different contents of the STEM areas involved, which are selected from the primary education curriculum. In addition, they are accompanied by a video, a didactic guide, and an observation sheet for the students, in order to focus their attention on the contents worked on.

### 2.5 Measuring instrument

Different measuring instruments have been designed and implemented according to the research objectives.

For Study 1 carried out with subsample 1, a questionnaire was designed divided into two sections (Questionnaire 1). The first section evaluated affective and competency aspects and consisted of 21 questions with 4 answer options. Some of the questions were aimed at verifying the degree of affectivity and appreciation of the student toward science in different contexts. Other questions asked were intended to diagnose the level of competence, capacity, or self-efficacy of the student participant in different real situations related to STEM tasks. As an initial diagnosis, the second

| Example of questions related to the affective and competence dimension | |
|---|---|
| 4. Do you like to learn science by doing experiments and hands-on tasks?<br>a. I love it<br>b. I'm good at it<br>c. I'm bad at it<br>d. It bores me | 7. Have you ever disassembled a toy to see what it's like inside?<br>a. Yes, I wanted to see how it worked<br>b. Yes, but it broke down<br>c. No, but I'd like to do it<br>d. Never |

**Table 1.**
*Example of questions related to the affective and competence dimension.*

| Example of questions related to the cognitive dimension | |
|---|---|
| 2. Julia and Henry are making a model with an electric circuit for school. What materials do they need for the circuit to work?<br>a. A battery, a light bulb, a switch, and the conductor wires<br>b. A wooden stand, a battery, and insulating cables<br>c. A battery, a light bulb, a conductor cable, and a wooden stand<br>d. Two batteries and a switch | 9. Laura's blender receives electricity from the grid by plugging it into an outlet. But into what do you think the mixer transforms the electricity it receives?<br>a. In motion so that the ingredients are well mixed<br>b. In heat so that the ingredients remain in a liquid state<br>c. In sound, that's why it makes so much noise when we use it |

**Table 2.**
*Example of questions related to the cognitive dimension.*

section of the questionnaire had the purpose of assessing the level of STEM knowledge of the students by means of 10 multiple choice questions about theoretical contents or situations of application of the contents. The content of these 10 questions is based on the education curriculum of the primary stage. **Table 1** shows some of the affective and competence questions of the first section of the questionnaire.

**Table 2** shows some questions from the second section aimed at assessing the level of STEM knowledge.

For Study 2 on the validation and implementation of STEM workshops with subsample 2, various questionnaires were designed according to the workshop topic. Specifically, for each workshop, one was developed as a pretest to evaluate the initial level of knowledge of the participating sample and another as a posttest to check whether student learning improved after the explanation of the contents by means of the two didactic methodologies used: that of the control group and that of the experimental group. The questions used in these questionnaires were based on the questions in the textbooks of the different publishers used by the students in the classroom. By way of example, one of the questions from workshop 3 is specified. "*When approaching a traffic light, a cyclist stops pedaling. For a while, however, the bicycle continues to move. What causes the bicycle to stop after a certain time*?"

## 3. Results

### 3.1 Results of Study 1: analysis of the cognitive, affective, and competence dimensions of primary school students in relation to STEM areas

First, a descriptive analysis of the cognitive dimension is presented and then the inferential analysis is detailed in order to test the proposed research hypotheses. Next, the results related to the affective dimension and finally those related to the competence dimension are represented.

#### *3.1.1 Cognitive dimension analysis*

The descriptive statistics obtained by subsample 1 ($n$ = 801 students) in the knowledge questionnaire are presented. Primary school students score an average of 5.38 points out of 10, with a standard deviation of 1.72. Although the score obtained suggests that students show knowledge about STEM content, the analysis by questions reveals that the level of knowledge is worse when it comes to answering purely theoretical questions. However, students scored better on content-related questions about real situations, coinciding with other studies [38, 9].

**Table 3** shows the descriptive statistics obtained in the STEM level of knowledge of primary school students according to the variable academic level.

As can be seen in **Table 3**, third-grade students score an average of 4.82 points out of 10; fourth-grade students score 5.46 points; fifth-grade students average 5.44 points; and sixth-grade students average 5.74 points. Regardless of the academic year, the cognitive level of the students is not very high, although it is true that there is a cognitive improvement with academic progress. However, the results obtained allow us to accept Hypothesis 1 "*Elementary students have a low level of knowledge in STEM areas.*" In order to verify the existence of statistically significant differences depending on the variable academic level, an ANOVA statistical test of one factor with Tukey's post hoc has been carried out. The results obtained are shown in **Tables 4** and **5**.

The data presented in **Table 4** show the existence of statistically significant differences in the STEM cognitive domain between academic courses obtaining a significance of 0.001. The analysis with Tukey's post hoc shown in **Table 5** indicates that these differences in the variable level of knowledge appear among third vs. fourth graders (Sig. = 0.005) and among third graders vs. sixth graders (Sig. = 0.000), favoring the average score to students in the upper grades in both cases. It seems evident that the STEM contents are dealt with in greater depth in the more advanced courses; however, it is necessary to pay attention to the didactic strategies used to avoid forgetting in the higher courses [39]. On the other hand, the data presented above make it possible to accept Hypothesis 2 "*There are differences in the level of knowledge in STEM areas of the primary students depending on the variable academic level.*"

| School year | Mean | Std. deviation | Std. error of the mean |
|---|---|---|---|
| 3rd PE | 4.82 | 1.59 | 0.13 |
| 4th PE | 5.46 | 1.71 | 0.11 |
| 5th PE | 5.44 | 1.50 | 0.18 |
| 6th PE | 5.74 | 1.84 | 0.15 |

**Table 3.**
*Descriptive statistics (academic level).*

| ANOVA | | Sum of squares | Df | Mean square | F | Sig. |
|---|---|---|---|---|---|---|
| Average score | Between groups | 61.775 | 3 | 20.592 | 7.111 | 0.001* |
| | Within groups | 1595.479 | 551 | 2.896 | | |
| | Total | 1657.254 | 554 | | | |

*Sig. < 0.05.

**Table 4.**
*One-factor ANOVA test (academic level).*

| (I) School year | (J) School year | Mean difference (I-J) | Std. error | Sig. | 95% confidence interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower bound | Upper bound |
| 3rd PE | 4th PE | −0.638 | 0.189 | 0.005* | −1.126 | −0.149 |
| | 6th PE | −0.917 | 0.203 | 0.000* | −1.442 | −0.392 |

*Sig. < 0.05.

**Table 5.**
*Tukey's HSD post hoc test (academic level).*

| | Mean | Std. deviation | Std. error of the mean |
|---|---|---|---|
| Men | 5.47 | 1.74 | 0.10 |
| Women | 5.32 | 1.69 | 0.10 |

**Table 6.**
*Descriptive statistics (gender).*

On the other hand, it is intended to analyze the influence of gender on the variable level of knowledge due to the numerous existing stereotypes in relation to the subject. Specifically, some authors [40] point out that girls outnumber boys when it comes to participating in class and doing homework, but boys do better on physics tests. Other studies [41] indicate that gender differences can be reduced with a value affirming intervention. On the other hand, [42] indicate that the gender gap in STEM disciplines goes beyond the limited representation of women since women actually score lower on exams and on standardized tests on scientific concepts. Other authors [43] also agree that women show a greater preference for studies related to the health sector (nursing, veterinary, or microbiology) and men choose careers such as architecture, engineering, physics, or computer science. **Table 6** shows the descriptive statistics according to the gender variable.

As can be seen in **Table 6**, boys score an average of 5.47 points with a standard deviation of 1.74. On the other hand, girls achieve a score of 5.32 points with a standard deviation of 1.69 points. These results seem to indicate that in the exploratory study carried out with subsample 1 (primary school students) there is STEM knowledge equity regardless of gender. Nevertheless, it was thought convenient to validate this assertion by means of an inferential analysis. **Table 7** shows the Student's t-test carried out.

As can be seen in **Table 7**, the value of the significance obtained was Sig. = 0.305, so we can accept Hypothesis 3 "*There are no statistically significant differences in the level of knowledge in STEM areas as a function of the gender variable.*"

| | T | Df | Sig. (2-tailed) | Mean difference | Std. error difference | 95% confidence interval of the difference | |
|---|---|---|---|---|---|---|---|
| | | | | | | Lower | Upper |
| Mean | 1.026 | 548 | 0.305* | 0.150 | 0.146 | −0.137 | 0.438 |

*Sig. < 0.05.

**Table 7.**
*Student's t-test (variable: gender).*

### *3.1.2 Analysis of the affective dimension*

The results obtained when analyzing the affective dimension in relation to STEM areas in formal and informal contexts are shown. **Tables 8–12** show the percentages obtained in some of the questions asked. The answers obtained in the different options are specified.

**Tables 8–12** show that elementary students show a positive attitude toward learning STEM areas in different contexts. The majority of participants show a favorable attitude in the statements within the educational environment (**Table 8**) and show a preference for experimental methodologies (**Table 9**). This fact is verified again when analyzing STEM learning issues in experimental or practical environments. Specifically, **Table 10** confirms the preference for practical teaching strategies. On the contrary, there is a decrease in the percentage of students who select the positive items in matters in which leisure is related to STEM areas. Generally, the percentages reached are mostly positive as can be seen in **Tables 11** and **12**, but negative attitudes increase in cases such as the choice of toys or television channel. Taking into account the results obtained in the affective-attitudinal dimension, we can accept Hypothesis 4 "*Primary school students show a favorable attitude toward STEM subjects and their learning.*"

| | | | | |
|---|---|---|---|---|
| 2. Do you like the activities you do in science classes? | I love them (48.0%) | I'm good at them (39.4%) | I'm bad at them (3.3%) | They bore me (8.9%) |

**Table 8.**
*Percent of students who select different items from Statement 2.*

| | | | | |
|---|---|---|---|---|
| 4. Do you like to learn science by doing experiments? | I love it (82.9%) | I'm good at it (11.0%) | I'm bad at it (3.7%) | It bores me (2.0%) |

**Table 9.**
*Percent of students who select different items from Statement 4.*

| | | | | |
|---|---|---|---|---|
| 6. Would you like to learn how to create robots? | I'd love to (70.7%) | Yes, I'd be good at it (11.0%) | No, I would not be good at it (11.8%) | No, I'd be bored (6.1%) |

**Table 10.**
*Percent of students who select different items from Statement 6.*

| | | | | |
|---|---|---|---|---|
| 17. Would you ask Santa Claus to bring you science games? | Yes, I love them (43.9%) | Maybe, they'll be entertaining (34.1%) | No, I would not know how to play (3.3%) | I prefer more fun games (15.0%) |

**Table 11.**
*Percent of students who select different items from Statement 17.*

| | | | | |
|---|---|---|---|---|
| 19. Do you like math puzzle books? | Yes, I love them (46.3%) | Yes, but I do not know how to solve them; I'd like to learn (29.3%) | No, I do not know how to solve them and they are useless (3.3%) | I'm not interested in them at all (19.1%) |

**Table 12.**
*Percent of students who select different items from Statement 19.*

### *3.1.3 Analysis of the competence dimension*

This section presents the results related to the level of competence and self-efficacy of primary school students in the resolution of different scientific-technological situations. **Tables 13–16** show some of the results of this section.

**Tables 13–16** show that, in general terms, subjects are considered competent when carrying out STEM activities, because in the items of positive self-efficacy percentages prevail. Specifically, Statement 7 (**Table 13**) is where the lowest levels of self-efficacy are obtained. On the contrary, in Statement 11 (**Table 14**) a higher percentage of students is observed in the positive items, especially in the item referring to positive self-efficacy with 45.9% of students, although it is true that 35% of students would request some help for its execution. The same occurs in Statement 14 (**Table 15**) and in Statement 21 (**Table 16**). In both cases, the majority of students show high levels of self-efficacy, with 51.6% of students indicating that they feel qualified in Statement 14 (**Table 15**) and up to 80.5% of students considering themselves capable of resolving without problems the task proposed in item 21 (**Table 16**). Based on these results, with respect to Hypothesis 5 (*Elementary students have low levels of proficiency in STEM areas*), it should be noted that it is partially accepted since the level of self-efficacy of the participating sample varies depending on the context of the task to be performed. On the other hand, it was decided to evaluate the results of the self-efficacy variable according to gender and it was obtained that there are no statistically significant differences (Sig. > 0.05) in this variable, allowing it to accept Hypothesis 6 "*There are no statistically significant differences in competency values with respect to the gender variable.*"

| | | | | |
|---|---|---|---|---|
| 7. Have you ever disassembled a toy to see what it's like inside? | Yes, I wanted to see how it worked (26.4%) | Yes, but it broke down (12.6%) | No, but I'd like to do it (29.7%) | Never (30.9%) |

**Table 13.**
*Percent of students who select different items from Statement 7.*

| | | | | |
|---|---|---|---|---|
| 11. If you had the necessary materials, would you be able to build a swing on a tree? | Yes, no problem (45.9%) | Yes, but with some help (35.0%) | No, but I'd try (17.5%) | I would not be able to build it (1.6%) |

**Table 14.**
*Percent of students who select different items from Statement 11.*

| | | | | |
|---|---|---|---|---|
| 14. Have you ever tried to repair a broken toy or device? | Yes, and I've fixed it (51.6%) | Yes, but I did not fix it (37.4%) | No, because I do not think I can fix it (5.3%) | No, because it bores me (3.7%) |

**Table 15.**
*Percent of students who select different items from Statement 14.*

| | | | | |
|---|---|---|---|---|
| 21. Do you like to set up a domino effect? | Yes, and the longer the better (80.5%) | Yes, but one that does not take long (10.6%) | I would not be able to finish it (2.4%) | No, I find it very boring (4.1%) |

**Table 16.**
*Percent of students who select different items from Statement 21.*

### 3.2 Results of Study 2: implementation and validation of STEM workshops as active didactic strategies that improve the teaching/learning of these areas in primary school students

**Figure 1** shows the results obtained in the pretest of the control and experimental groups that make up subsample 2.

The results shown in **Figure 1** show the existence of a low level of knowledge on the part of primary school pupils before carrying out the different didactic interventions, both in the control groups and in the experimental groups of the different schools. This is due to the fact that it was decided that contents that were not previously studied by the students of the participating groups will be chosen, in order to establish a homogeneous starting point between both. It can be observed (**Figure 1**) that no group obtains a passing grade. Likewise, the inferential analysis carried out revealed that there were no statistically significant differences (Sig. > 0.05) in the mean scores of the control and experimental group and that both groups started with the same level of STEM knowledge and with similar science preconceptions.

**Figure 2** shows the results obtained in the posttest of the different groups, revealing a notable cognitive improvement in all cases after the didactic interventions exposed to the control groups and after the STEM workshops carried out in the experimental groups.

As shown in **Figure 2**, it can be verified that all students improve their STEM knowledge level after the didactic interventions, regardless of the type of teaching applied. However, the students in the experimental groups have not only improved their score with respect to the pretest but also obtained higher scores than the students in the control groups. Active strategies are considered the best method for teaching science, promoting research skills in students and helping them internalize new knowledge in the search for answers to previously formulated scientific questions [44]. It seems clear that the experimental group has improved its average score with respect to the pretest and more easily remembered the contents than the control group. However, a Student's t-test was conducted to check for statistically significant differences in mean scores between groups. The results are shown in **Table 17**.

As can be seen in **Table 17**, there is a mean difference of 1.33 points out of 10 in School 1 with a significance of 0.013, favoring the experimental group. In School 2, a mean difference of 1.23 points out of 10 was obtained in favor of the experimental group, also obtaining a significance of 0.043. Likewise, in School 3, a mean

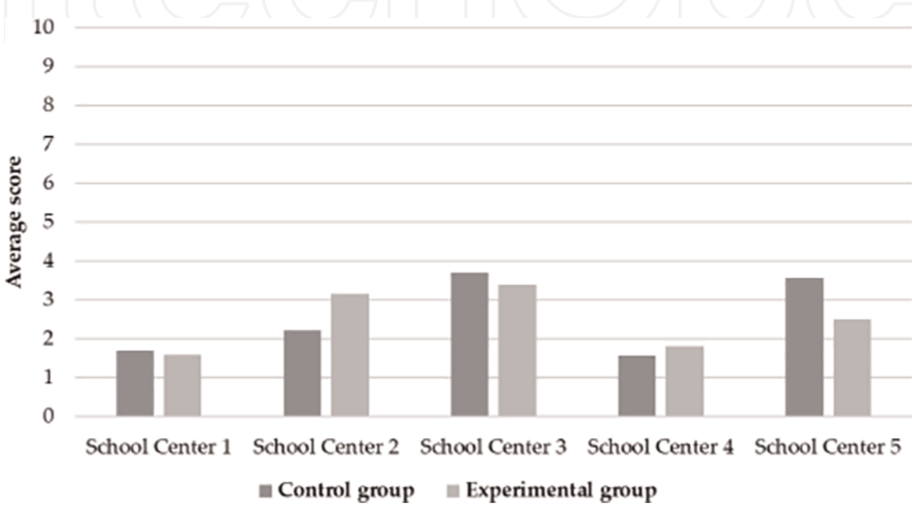


**Figure 1.**
*Pretest results.*

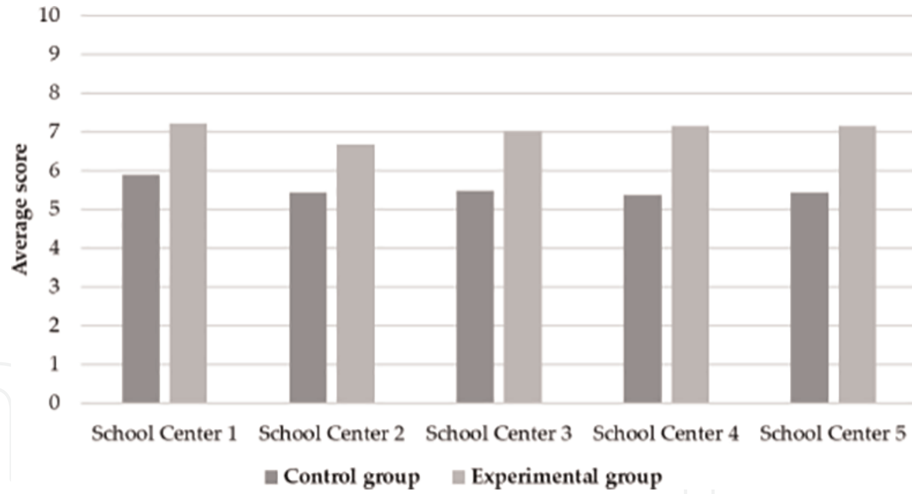


**Figure 2.**
*Posttest results.*

| Post-test | t | Sig. (2-tailed) | Mean difference | Std. error difference | 95% confidence interval of the difference | |
|---|---|---|---|---|---|---|
| | | | | | Lower | Upper |
| School center 1 | −2.586 | 0.013* | −1.333 | 0.515 | −2.375 | −0.291 |
| School center 2 | −2.087 | 0.043* | −1.238 | 0.593 | −2.437 | −0.039 |
| School center 3 | −3.428 | 0.001* | −1.560 | 0.455 | −2.474 | −0.647 |
| School center 4 | −3.940 | 0.000* | −1.771 | 0.449 | −2.678 | −0.864 |
| School center 5 | 5.756 | 0.000* | −2.083 | 0.361 | 1.356 | 2.810 |

*Sig. < 0.05.*

**Table 17.**
*Student's t-test (control group vs. experimental group).*

difference of 1.56 points was obtained in favor of the experimental group, leading to the existence of statistically significant differences (Sig. = 0.001) between groups. In School 4, there is a mean difference of 1.77 points out of 10 and there is a significance of 0.013 in favor of the experimental group. Finally, in School 5, there is a mean difference of 2.08 points out of 10 and a significance of <0.0001 in favor of the experimental group. The results reveal that there are statistically significant differences between the control and experimental groups in favor of the latter and consequently validate the effectiveness of STEM workshops in learning. The proposed STEM workshops have made it possible to address competence skills in the classroom and to use relevant everyday contexts of real life to promote STEM motivation and learning in a meaningful and contextualized way [45].

With respect to the emotional variable, the degree of manifestation of positive and negative emotions expressed by the experimental groups before and after the explanation of the contents through the STEM workshops is shown in **Figure 3** by way of example. It can be observed that after the realization of the STEM workshops the primary students significantly increase (Sig. < 0.05) their positive emotions (fun, interest, joy, or confidence), decreasing the degree of manifestation of negative emotions such as stress, desperation, worry, or sadness.

The results obtained after the implementation of the STEM workshops shown above allow us to accept Hypothesis 7 "*The implementation of STEM workshops in the primary classroom as didactic strategies produces a cognitive and emotional evolution in*

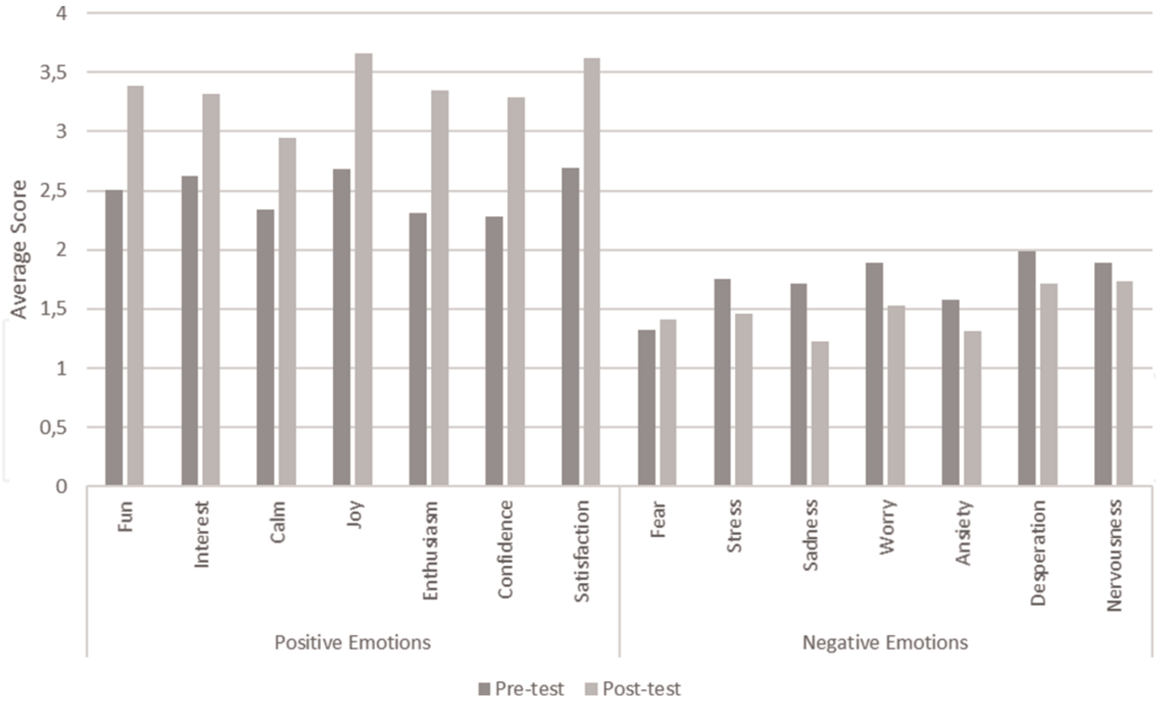


**Figure 3.**
*Emotional results obtained by the experimental groups.*

*the students*" and Hypothesis 8 "*There are statistically significant differences in cognitive and affective variables between the students who use a traditional methodology and those who use a methodology based on the implementation of STEM workshops.*"

## 4. Discussion

The results show a favorable trend toward STEM areas among primary school students. Although recent studies by some authors [22] indicate that there is a significant decline in students' attitudes toward school science throughout primary school, this research argues that primary school students show great interest and enthusiasm for science subjects and their learning, coinciding with other work [46], and the students are generally competent in this field. However, the results on cognitive domain tend to make us reflect on whether the chosen teaching methods are the most suitable for meaningful STEM learning, since there is a certain lack of knowledge on the subject, thus coinciding with previous scientific literature [47, 48]. It is important to know to what extent students, once they have completed their schooling, are adequately prepared to apply knowledge in understanding important issues and in solving significant problems [49], since inadequate scientific training from an early age will have a negative impact on future learning and attitudes.

In addition, the results show that hands-on, experimental activity generates motivation and a desire to learn [50]. Along these lines, it would be convenient to adapt the teaching style of the teachers to the preferences and way of learning of the students in order to improve and facilitate the teaching-learning process [51]. Furthermore, we consider that in order to promote scientific and technological literacy in the long term, it will be decisive for the educational system to promote practical activities, projects, and competency workshops [24]. The scores obtained by the experimental groups show that the experiences made in the workshops help to eliminate firmly rooted misconceptions in the students and allow the acquisition of contents that are difficult to understand when the phenomenon studied is observed directly [24]. On the contrary, the results of the control groups show that textbooks and traditional strategies only develop scientific knowledge and are governed by the internal logic of science, without asking what science is, how it develops, or what benefits it brings to society [52]. It should also be noted that despite existing stereotypes about gender inequality problems and claims that science and technology are mainly male-dominated fields [41], the results of this study with respect to cognitive and self-efficacy domains show that there are no gender differences in STEM areas at the elementary stage of education.

It is therefore considered necessary to create and study new resources and methodologies that facilitate and motivate the learning of STEM areas and promote thinking strategies for students in the different early stages of their education. The proposed didactic model based on STEM workshops provides an appropriate environment for primary school pupils to learn to be creative, to solve real challenges or problems, and to improve not only STEM competences but also other competences such as collaborative learning, the use of virtual scenarios, the creation of informal learning opportunities, and actively sharing learning with others [53]. Along these lines, we agree with other studies [33, 54] that there is a positive and significant relationship between STEM-integrated learning and students' academic achievements, interests, and aspirations in relation to these areas.

Likewise, these new educational strategies make it possible to acquire higher cognitive levels of science and technology in students of all ages, and more specifically from early ages, where interest in science generates positive emotions and attitudes [8]. From this perspective, the aim of STEM education, rather than replacing spontaneous ideas with scientific ones, is to provide individuals with new explanatory models for interpreting the world and to help them recognize that scientific knowledge is, in many cases, more appropriate than their misconceptions for describing or understanding certain phenomena [55]. The use of experimentation in the classroom will promote a willingness to learn, will make it easier for children to face tasks, and will make it easier for them to achieve objectives, and, in addition, the goals achieved will be much greater [24]. In brief, STEM education involves working in the context of complex phenomena or situations that require students to use knowledge and skills from multiple disciplines to solve real-world problems [26]. With all the above, it is finally concluded that personal factors such as interests, attitudes, and beliefs about self-efficacy will be key aspects to influence the choice of STEM subjects and the professional expectations of students [19].

## 5. Conclusion

Once the different variables of the study have been analyzed, we can conclude that traditional activities are, in general, boring for the students and do not help their learning to be effective and lasting. On the contrary, the implementation of STEM practical experiences in formal contexts generates a favorable framework to promote the learning of technical and manipulative skills and fosters underdeveloped research skills in primary school students, such as the habit of formulating hypotheses, experimenting, establishing their own conclusions, and being critical, while respecting the conclusions of their peers.

In addition, students seem to understand that learning through hands-on, active learning strategies is enriching, facilitates the task of learning and acquiring knowledge, and is fun, entertaining, and motivating.

The results obtained allow us to highlight the importance of educators using active teaching methodologies that involve a greater role for their pupils. Thus, students realize that there are many ways to present STEM areas, beyond the mere theoretical master class, but without ever losing sight of the scientific rigor.

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