sustainability

MDPI

Article

Learning Science in Primary Education with STEM Workshops: Analysis of Teaching Effectiveness from a Cognitive and Emotional Perspective

Milagros Mateos-Núñez, Guadalupe Martínez-Borreguero * and Francisco Luis Naranjo-Correa

Department of Science Teaching, University of Extremadura, 06006 Badajoz, Spain; milagrosmateos@unex.es (M.M.-N.); naranjo@unex.es (F.L.N.-C.)

* Correspondence: mmarbor@unex.es; Tel.: +34-924-289-300

Received: 26 February 2020; Accepted: 10 April 2020; Published: 12 April 2020

Abstract: Several international institutions emphasize the need to develop a comprehensive education in STEM areas (Science, Technology, Engineering, Mathematics) to improve learning, competences and student perception of these subjects. The general objective of this study was to analyze the teaching effectiveness, from a cognitive and emotional perspective, of a STEM workshop versus an academic-expositional methodology in the science classroom in primary education. The research design was quasi-experimental with a control group, an experimental group, a pre-test and two post-tests. By means of a randomized probabilistic sampling, 256 students between 10 and 12 years old participated. Cognitive, emotional, attitudinal and gender variables were analyzed according to two teaching methodologies, an expository academic methodology for the control group and an active methodology based on the development of a practical STEM workshop for the experimental group. The results reveal that both methodologies are equally effective in short-term learning, but statistically significant differences are found in long-term learning, in favor of STEM workshops. Likewise, the STEM workshop mainly generates positive emotions and attitudes in the students compared to the transmission-reception methodology applied with the control group.

Keywords: STEM education; primary education; science teaching; active teaching methodologies

1. Introduction

The new educational perspectives focused on scientific literacy seem to agree on the importance of science and technology teaching to consider not only conceptual content as educational objectives. There is also a need for those other objectives that have to do with the processes of science, its implications for technology and society (STS), or the shaping of personally and socially important attitudes, values, and rules [1,2]. However, currently, science education poses great challenges for teachers, who must not only respond to the demands of how to teach and bring to the science classroom the curricular proposals, but also find the most adequate way to connect with students so that they learn meaningfully and develop the skills, attitudes, and values that they will need in the world they will face [3,4].

More specifically, changes in society demand science education that is consistent with new realities where people know how to access acquired knowledge and produce new information using the knowledge they have gained [5]. However, the lack of practical work-based teaching strategies in primary schools does not contribute effectively to the acquisition of scientific or technological skills, which is reflected in students moving on to secondary education [6–8]. This also leads to a decline in students' scientific vocations, since according to some authors [9], there is a strong positive relationship between students' experiences with science in school and their choice of future studies in STEM disciplines (Science, Technology, Engineering and Mathematics).

Some studies [10,11] explain that education should not be reduced only to basics such as academics, information gathering and processing, or strictly cognitive development, but should also include the emotional dimension, since both dimensions affect the teaching and learning process. In fact, one of the main causes of the lack of interest in scientific disciplines is due to a negative attitude towards science, as indicated by some authors [12,13]. In this line, other researches argue that scientific activities that are attractive to students can generate positive emotions and social interactions, as opposed to teaching methodologies that are mainly focused on the acquisition of theoretical knowledge of a certain complexity and little connected to real life [14,15].

In order to address this problem, in recent years, the traditional academic-expositional models, based on the transmission of theoretical knowledge, have been complemented by other active teaching models in which the experiences that give rise to the active construction of knowledge take precedence [16]. However, recent studies [17] show that the use of traditional teaching methods continues to predominate in science and technology education, even though it is known that these strategies induce students to adopt a passive role, do little to foster student interest and produce high levels of academic failure, especially in scientific subjects such as physics and mathematics [15,18]. On this basis, it is considered necessary to create and study new resources and methodologies that facilitate and motivate student learning in scientific and technological areas in the early stages of their education [19,20].

In line with these approaches, educational programs focused on STEM education have aroused the interest of politicians, researchers, teachers and students concerned with improving and gaining access to better scientific literacy [21]. Today, STEM education is widely accepted as a method that synthesizes mathematics, engineering, technology, and science for critical thinking, creativity, innovation, and real-world problem solving [22,23]. Specifically, some authors [24] define STEM education as an approach in which students are taught content in science, technology, mathematics and engineering across disciplines in contexts involving real-life problems to enrich their learning and scientific literacy. Thus, research suggests that schools that focus on STEM education have a positive effect on student learning and STEM skills. For example, findings from other studies [25] confirm that students who participate in STEM programs perform better on math and science tests than those who do not participate in such programs. These authors also conclude that students in STEM programs are more likely to specialize in STEM subjects in higher education and even to choose careers in these areas. In addition, other research [26] found that attending STEM programs increases the likelihood that students will improve their math and science proficiency in high school, enhances participation in extracurricular STEM activities, and increases interest in science careers and aspirations for higher degrees in these areas. Likewise, some studies [27] have shown that STEM schools have a positive effect on the average grades of students in STEM subjects and, therefore, can significantly influence academic performance in later years.

Given this scenario, the vision that teachers have about such aspects takes a great role. It is essential to know the trends in the beliefs of science teachers in initial training regarding this type of challenge, and their willingness to incorporate them into science and technology teaching [4]. The position that science teachers in training take on the aspects covered by teaching methodology will influence their innovative capacity and their willingness to create favorable contexts capable of promoting learning in the terms established by current trends [28]. However, according to other authors [29], the beliefs of future teachers regarding active teaching models are strongly influenced by their life experiences as teachers and students. For this reason, guiding teachers in initial training to recognize the need to innovate in science and technology teaching in the direction mentioned above, requires that during the training process there be an adequate relationship between theory and practice so that the future teacher can make didactic decisions based on this new educational paradigm [4].

On the other hand, several studies recognize that the affective dimension must be considered and encouraged in science education and, therefore, must be part of its educational background [30], since it has been shown that the affective and cognitive domains are mutually conditioned. Emotions influence learning while learning outcomes influence emotions [31].

Considering the relationship between the affective-emotional dimension and learning, numerous studies have shown that one way to generate positive emotions in students is to implement hands-on activities [15,32,33]. Along these lines, we agree with [34] that STEM education programs can be decisive not only in learning, but also in the attitude and commitment of students towards STEM subjects.

As a result of the need to promote the development of scientific literacy and to involve students in the learning of STEM areas, in this research, a STEM workshop was designed and implemented with primary school students in order to analyze its teaching effectiveness in the face of academic-expositional teaching from both a cognitive and emotional perspective. In this sense, we consider the concept of teaching effectiveness in the framework of this research as the usefulness of the intervention carried out in the classroom. Specifically, an intervention is effective or useful from a didactic point of view, if it contributes to student learning (cognitive dimension) or to improving students' emotions and attitudes towards the subject being taught (affective dimension). To understand the term cognitive dimension or cognitive ability, it is necessary to consider the development of the cognitive theory of learning. Cognitive theory argues that knowledge is constructed from the student's immediate environment in an active and meaningful way, since learning involves cognitive processing of information rather than mere mechanical memorization of information [35,36]. The emotional dimension is linked to the previous dimension since, according to some authors [37], emotions are also closely linked to the teaching-learning of concrete knowledge. There are a variety of taxonomies for referring to emotions [13]. One of the most accepted in the field of didactics of experimental sciences is that provided by [38], who indicates that emotions are not only reactions to the stimuli of the present, but are also produced by the memory or evocation of events that happened in the past or by the anticipation of possible future situations. Consequently, we assume that emotions have a psychobiological part [39], but they are also a social construction [40] interconnected with context and culture [41].

2. Materials and Methods

The research design was quasi-experimental with a control group, an experimental group, a pre-test and two post-tests. The didactic methodology used was selected as an independent variable, and the learning achieved by the students at the end of the didactic intervention, the emotions and attitudes expressed by the participants, as dependent variables. With the control group, a more traditional teaching methodology was used, based on the expository academic model for the explanation of the contents under study. Specifically, it was based on presentations and theoretical explanations. During these sessions, the students intervened and argued their ideas by asking the questions they considered appropriate and discussing the situations posed by the teacher. However, with the experimental group, a more active methodology was used, focused on the development of a practical STEM workshop following the indications of previous works [42]. Specifically, a STEM workshop was designed to learn about primary education issues related to forces and movement. Specifically, the selected contents of the science curriculum were forces, motion, deformations of bodies and Newton's laws. The aim was to analyze the influence of the use of two teaching methodologies, on the one hand, in the learning of the selected STEM contents, and on the other hand, in the affective and attitudinal domain of the students. Likewise, the aim was to verify whether the concepts learned through the different teaching methodologies used persist over time, or whether, on the contrary, they are forgotten.

2.1. Objectives

The main objective of the research carried out was to analyze the teaching effectiveness, from a cognitive and emotional perspective, of a STEM workshop versus an academic-expositional methodology in the primary education science classroom.

This general objective was broken down into the following specific objectives.

- Specific Objective 1 (SO1): To analyze the initial level of knowledge of the participating subjects in relation to the selected contents.
- Specific Objective 2 (SO2): To compare the level of knowledge acquired by primary school pupils in two educational interventions, one based on the use of STEM workshops and the other more traditional, based on an expository academic model.
- Specific Objective 3 (SO3): To check if the learning acquired by the students after the implementation of the didactic interventions is maintained over time.
- Specific Objective 4 (SO4): To analyze the emotions and attitudes manifested by primary school students during the implemented didactic interventions.
- Specific Objective 5 (SO5): To check if there are affective-emotional differences in the participating sample according to the type of didactic intervention developed.
- Specific Objective 6 (SO6): To analyze the cognitive variables according to the gender of the participants.

2.2. Hypothesis

Based on the proposed objectives, the following hypotheses were formulated:

Hypothesis 1 (H1). *The participating sample presents a low level of initial knowledge in the contents under study.*

Hypothesis 2 (H2). *There are statistically significant differences in the level of knowledge of the students after the implementation of the didactic interventions compared to their initial level of knowledge, regardless of the methodology applied.*

Hypothesis 3 (H3). *The implementation of STEM workshops facilitates meaningful, long-term learning for primary school students compared to expository academic intervention in the science classroom.*

Hypothesis 4 (H4). *The implementation of the STEM workshop with the experimental group mainly generates positive emotions in primary education students compared to the transmission-reception methodology applied with the control group.*

Hypothesis 5 (H5). *The implementation of the STEM workshop with the experimental group mainly generates positive attitudes in the primary education students compared to the transmission-reception methodology applied with the control group.*

Hypothesis 6 (H6). *Participating male students show a higher level of knowledge of the selected STEM content than participating female students throughout the study.*

2.3. Sample of Research

The participating sample in the research was selected based on a random and probabilistic sampling. Specifically, it consisted of 256 students belonging to the academic levels of 5th and 6th grade of primary education, aged between 10 and 12 years. These students were divided into two groups, control and experimental, which were homogeneous and equivalent in terms of ability, discipline and academic performance in previous years. Table 1 shows the distribution of the participating sample according to group and gender.

Table 1. Distribution of the sample by gender.

Group	Gender	
	Male	**Female**
Control Group	52	60
Experimental Group	67	77

2.4. Instrument and Procedures

A pre-test and two post-tests were designed as measurement instruments, to assess the variables referred to both the cognitive and affective domains based on previous research [15,43]. First, the pre-test was implemented as a previous step to the teaching-learning process of the selected contents. Later, the implementation of the didactic methodologies was carried out both in the control group and in the experimental group. At the end of the didactic intervention in both cases, post-test I was performed. Finally, in order to know the long-term learning results, post-test II was carried out by the students months after the explanation of the contents. The basic strategy for the application of the instruments consisted of giving the tests to the participants personally, making clear the anonymous and voluntary participation and the confidentiality of the information. The measurement instruments were the same for the control group and the experimental group.

The pre-test was composed of multiple-choice questions with four options for the answer, where only one was correct, referring to both conceptual and procedural contents related to the contents selected for the research. Specifically, the contents of the selected science curriculum were forces, motion, deformations of bodies and Newton's laws. Similarly, the post-tests, both post-test I and post-test II, consisted of a section with 12 multiple-choice questions of a theoretical and procedural nature to analyze the level of knowledge of the students after the didactic interventions developed. Additionally, a section was included in these instruments to measure the emotional and attitudinal variables of the subjects. Specifically, and based on previous research [13,15,43], 8 emotions were included, 4 positives and 4 negatives. The selected emotions were curiosity, fun, confidence, satisfaction, disgust, boredom, worry and anger. The students had to indicate whether they had felt each emotion during the teaching interventions. Finally, in order to assess the students' attitudes, 10 statements were included on methodological, learning and self-efficacy aspects related to what was discussed in the classroom. The difference between post-test I and post-test II was that post-test II was passed on to the students several months later, to check whether they remembered the contents learned or had forgotten them over time.

It should be noted that the process of measuring the teaching effectiveness of the interventions carried out with the students was the following, based on the definition of teaching effectiveness considered in the framework of this research (i.e., the usefulness of the intervention carried out in the classroom). The teaching effectiveness of the interventions carried out in the classroom is measured based on two variables, one cognitive and the other affective. On the one hand, the variable level of knowledge was quantified before the intervention and on the other hand, it was quantified after the didactic intervention, at two different moments, using a pre-test and two post-tests. The increase in the level of knowledge variable indicates the learning achieved by the students in the different interventions carried out. It is considered that the didactic intervention was useful or effective if there are statistically significant differences between the initial and final state of the student's level of knowledge in post-test I, and if the content learned by the student is not forgotten over time (results of post-test II). That is, if meaningful and long-term learning takes place in the students. Likewise, it was considered in the framework of this research that a didactic intervention is effective if it produces an improvement in the affective dimension of the students. To this end, the emotions that the student expresses before and after the didactic interventions were measured. Thus, if an increase in positive emotions or a decrease in negative emotions is produced, the intervention is considered to be effective from a didactic perspective in the affective domain.

As an example, Table 2 shows some questions to assess the level of knowledge of the students.

Table 2. Examples of questions to assess the level of knowledge of students.

Over which of the following floors or surfaces will a toy car that you push by hand be slower? (a) The car will move the same on any surface because the force you have pushed it with is the same. (b) A marble surface or floor. (c) The car will not move on any surface. (d) A stone surface or floor.	**Which of the following statements is true?** (a) The greater the force you apply to a one-kilogram object, the greater the acceleration. (b) The less force you apply to a one-kilogram object, the greater the acceleration. (c) The greater the mass of an object, the faster it will move when the same force is applied. (d) If you do not apply a force to an object that is standing still, that object will begin to move.
If we apply the same force to a toy car with a mass of 2 kg and a car with a mass of 4 kg, then . . . (a) The 2 kg car will move at the same speed as the 4 kg car. (b) The 2 kg car will move faster than the 4 kg car. (c) The 4 kg car will move faster than the 2 kg car. (d) The 4 kg car will stop after the 2 kg car.	**If you kick a small ball that was initially standing . . .** (a) The ball won't move. (b) The ball will start moving in the direction you kicked it. (c) The greater the force of the kick, the less speed the ball will acquire. (d) Due to the force of the kick, the ball will change its mass.

2.5. Validation of the Evaluation Instrument: Calibration Indexes

To validate the questionnaires concerning cognitive domain, several psychometric tests were carried out based on various studies [44–46]. Specifically, statistical tests were conducted focusing on the assessment of questionnaire items such as difficulty index and discrimination indexes. Correlations were estimated using the point biserial coefficient and Ferguson's Delta. Finally, the reliability of the instrument was calculated by means of the Kuder-Richardson Formula 20. For all these calculations, the formulas specified in the previous studies were used. Table 3 shows the values obtained and the recommended values [44–46] of the calculated indexes. All values are within the recommended range.

Table 3. Psychometric analysis of the questionnaire developed.

Coefficient	Obtained Value	Recommended Value
Mean difficulty index (P)	0.77	[0.30–0.90]
Mean discrimination index 1 (D1)	0.44	≥0.30
Mean discrimination index 2 (D2)	0.65	≥0.50
Mean point biserial coefficient (r_{pb})	0.46	≥0.20
Ferguson's delta (δ)	0.92	≥0.90
KR-20	0.67	≥0.60

The mean difficulty index (P) indicates the degree of difficulty of the questionnaire. This index was calculated for all the questions, obtaining values in all of them within the established ranges. We can see in Table 3 that an average value of P = 0.77 is obtained, so the degree of conceptual difficulty of the instrument is adequate for the research.

With respect to the discrimination indexes (D), the discrimination index 1 (D1) was calculated, which measures the discriminatory power of the questionnaire. That is, it indicates whether the questionnaire can distinguish those subjects with a more solid knowledge who answer correctly, from those subjects whose understanding is weaker. The value obtained was D1 = 0.44 which indicates a correct discrimination index. The discrimination index 2 (D2) indicates the proportion of successes in the group of students with better grades in relation to the total number of successes. It can be considered satisfactory if it is at least higher than 0.50 and in this case, this fact is fulfilled in all questions. Specifically, a value of D2 = 0.65 has been obtained, considered as good by the literature.

The point biserial coefficient (r) reflects the correlation between the scores of the subjects on one item with the scores on the whole test, and its range is [−1, +1]. If an item is positively correlated with the entire test, it means that subjects with high total scores are more likely to respond than subjects with low total scores. The average point biserial coefficient of the questionnaire is r = 0.46, so it also meets the recommended criterion.

Another source of evidence about the discriminatory power of the questionnaire calculated was Ferguson's Delta (δ). The literature indicates that a test that offers good discrimination power will have values of δ greater than 0.90. In this case, as can be seen in Table 3, the value obtained was δ = 0.92, so the questionnaire offers good discrimination power.

Finally, as shown in Table 3, the value obtained for Kuder-Richardson 20 coefficient was 0.67. According to the literature, this indicates an adequate reliability value for the instrument used.

2.6. Design of the STEM Workshops

STEM workshops have many positive aspects in the educational process [42,47] but students also have an important role as being responsible for their own learning. For the design of the workshops with the experimental group, the following guidelines were considered:

- The workshops are to be held in 2–3 sessions.
- The materials for their design must be easily acquired or recycled to facilitate their reproduction in non-formal contexts and be able to develop social values of respect, tolerance and empathy towards the socio-environmental context.
- The students will be distributed in small groups (3 or 4 students).
- The workshops must be based on current educational legislation.

Once the general guidelines were set out, the workshops held with the students are briefly explained. In the STEM workshop, two models were built. The first model, "Action-Reaction Car", was mainly used to experience Newton's laws with the students. With the second model, "Elasticar", mostly contents related to deformations caused by forces are explained. Figure 1 shows an image of the models made by students belonging to the experimental group.

Figure 1. Photographs of some models built in the STEM workshops.

3. Results

This section shows the results obtained in the research. IBM SPSS Statistics 20.0 software was used for data analysis and subsequent interpretation of the results. Two types of analysis were performed, a descriptive-exploratory analysis and an inferential analysis. In the case of inferential analysis, the Student's t-parametric test was used, considering the appropriate tests of normality. It should also be noted that in all the tests, a significance level of 0.05 was considered.

3.1. Results Obtained in the Pre-Test

The realization of the pre-test was based on all those studies that indicate that to address the conceptual errors of students, teachers must first know their previous ideas and conceptual schemes [48–50].

The results obtained in the pre-test suggest that the students were familiar with the contents set out in general terms, as the average score achieved was above the minimum average. The selected contents were studied in previous years by the students. Table 4 shows the descriptive statistics referring to the control group and the experimental group extracted from the pre-test.

Table 4. Pre-test descriptives (Variable: Study group. Control group vs. Experimental group).

Pre-Test	n	Mean	Std. Deviation	Std. Error Mean
Experimental Group	144	6.53	1.74	0.161
Control Group	112	5.84	1.83	0.173

These results can be justified with the previous explanation of the contents by the tutor before the intervention with the STEM workshops, i.e., the respondents had previously worked on the curriculum in class. However, it is assumed that some previous erroneous ideas are still held by students, since, coinciding with [51], at the end of the syllabus, there is often evidence of misunderstanding of the most fundamental concepts, and errors of interpretation continue to be made in the study of physical phenomena, even when they are taught repeatedly. Thus, the descriptive statistical analysis carried out by questions determined that there was a clear lack of understanding in concepts such as friction force (question 4 of the pre-test), deformations produced by forces (question 6 of the pre-test) but above all, it was observed that the students did not know how to apply the theoretical contents to real procedural situations.

On the other hand, an inferential statistical analysis was carried out to check the existence of statistically significant differences in the initial level of knowledge between the control and experimental groups. The Student's t-parametric test was chosen when it was verified that the conditions required in that test were met. The results obtained are shown in Table 5.

Table 5. Student's t-test in the pre-test (Variable: Study group. Experimental Group vs. Control Group).

t	df	Sig. (2-Tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
					Lower	Upper
−2.833	226	0.005 *	−0.67040	0.23661	−1.13663	−0.20416

* Sig. < 0.05.

Table 5 shows that there are statistically significant differences between the control group and the experimental group in relation to the initial level of knowledge, since the significance obtained was 0.005. Specifically, there is an average difference of 0.67 points out of 10 in favor of the experimental group that will be considered in the analysis of the level of knowledge after the didactic interventions. The above data imply the rejection of Hypothesis 1 raised in the research "The participating sample presents a low level of initial knowledge in the contents under study" since the cognitive results have not been as negative as expected (that is, less than 5 points out of 10 on average).

To conclude this section, the analysis of the level of knowledge carried out according to the gender of the students is shown below. This observation arises from the numerous studies that indicate that women show less interest and obtain lower scores on tests and standardized tests of conceptual domain related to STEM areas [52,53]. In this regard, Table 6 shows the descriptive statistics by gender and Table 7 shows the inferential analysis carried out to check whether there are statistically significant differences between the mean scores obtained by the two sets.

Table 6. Pre-test descriptives (Variable: Gender. Women vs. Men).

Gender	Mean	Std. Deviation	Std. Error Mean
Men	5.93	1.73	0.17
Women	6.43	1.85	0.16

Table 7. Student's t-test in the pre-test (Variable: Gender. Women vs. Men).

t	df	Sig. (2-Tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
					Lower	Upper
−2.093	226	0.037 *	−0.50100	0.23936	−0.97266	−0.02934

* Sig. < 0.05.

The results shown in Tables 6 and 7 indicate that there are differences between the level of knowledge shown by boys and girls and, moreover, these differences are statistically significant (Sig. = 0.037) in favor of the female collective. In this sense, we can reject Hypothesis 6 "Participating male students show a higher level of knowledge of the selected STEM content than participating female students" because the opposite has been observed.

3.2. Results Obtained in Post-Test I

The following are the descriptive results extracted from the post-test I carried out by the students at the end of the didactic interventions. Table 8 shows the descriptive statistics obtained by the sample participating in this questionnaire.

Table 8. Post-test I descriptives (Variable: Study group. Control group vs. Experimental group).

Post-Test I	n	Mean	Std. Deviation	Std. Error Mean
Experimental Group	144	8.09	1.61	0.13
Control Group	112	7.26	1.99	0.18

Comparing these results with those of the pre-test, both groups have significantly improved their mean score with respect to the pre-test. However, this statement is corroborated by performing a Student's t-test. Specifically, a significance of Sig. < 0.001 (in favor of post-test I vs. pre-test) is obtained in the case of the experimental group and a value of Sig. < 0.001 (in favor of post-test I vs. pre-test) in the case of the control group when comparing the means of post-test I with those obtained in the pre-test in each group.

These results reveal that both didactic interventions have been effective, since the students in both groups obtain average grades higher than those shown in the initial level of knowledge. Likewise, the analysis by question reveals an increase in the average scores with respect to those obtained in the pretest in the different questions, that is, there has been a cognitive improvement in the students after the explanations, by increasing the average scores, for example, in the questions referring to deformations, friction force or the more procedural questions.

In addition, an inferential analysis was performed between the average scores of the post-test I of the control group versus the experimental group. Several statistical tests were previously performed in order to choose a parametric or non-parametric mean contrast. The results suggest a choice of parametric tests so the Student's t-test for independent samples has been used for the comparison between groups. The results are shown in Table 9.

Table 9. Student's t-test in the post-test I (Variable: Study group. Experimental Group vs. Control Group).

t	df	Sig. (2-Tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
					Lower	Upper
−3.634	248	<0.001 *	−0.82988	0.22835	−1.27964	−0.38013

* Sig. < 0.05.

As shown in Table 9, there are statistically significant differences between groups (Sig. < 0.001). However, this difference of 0.83 points out of 10 in favor of the experimental group is evident since the starting point or level of initial knowledge was not the same in the two groups, as obtained in the pre-test. Although the results suggest that the active participation of the experimental group during the explanation of the contents has facilitated, to a greater extent, their acquisition, the data seem to indicate that the two didactic interventions developed have increased, in the same way, the initial level of knowledge of the students, considering that both are equally effective from a didactic point of view. This allows us to accept Hypothesis 2 proposed in research: "There are statistically significant differences in the level of knowledge of the students after the implementation of the didactic interventions compared to their initial level of knowledge, regardless of the methodology applied". To check the effect size of the statistically significant differences found in post-test I of the control and experimental groups, we calculated Cohen's delta value, represented by d [54]. Specifically, a value of d = 1.77 was obtained. This result reveals an effect size classified in the literature as high.

On the other hand, to verify the possible influence of the gender variable in the results, the descriptive statistics by gender are presented in Tables 10 and 11, and the inferential analysis carried out to check if there are statistically significant differences between the average scores obtained according to this variable.

Table 10. Post-test I descriptives (Variable: Gender. Women vs. Men).

Gender	Mean	Std. Deviation	Std. Error Mean
Men	7.5647	2.05642	0.19093
Women	7.8545	1.62343	0.14024

Table 11. Student's t-test in the post-test I (Variable: Gender. Women vs. Men).

t	df	Sig. (2-Tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
					Lower	Upper
−1.244	248	0.215	−0.28982	0.23296	−0.74866	0.16901

Although the data shown in Table 10 indicate that girls scored higher in post-test I than boys, the inferential analysis in Table 11 confirms that this mean difference is not statistically significant (Sig = 0.215). This allows us to reject again, as it happened in the pre-test, the Hypothesis 6 "Participating male students show a higher level of knowledge of the selected STEM content than participating female students", since no difference in the level of statistically significant knowledge is found according to this variable.

3.3. Results Obtained in Post-Test II

Finally, in order to validate the long-term teaching effectiveness of the STEM workshops compared to the academic-expositional methodology, the students participating in the study carried out a third questionnaire (post-test II) several months after the intervention, since the didactic validity of both methodologies in the short-term was demonstrated with the results shown in the previous section (results in post-test I).

Table 12 shows the descriptive statistics obtained by the participant sample in the post-test II carried out by the students months after implementing the designed didactic interventions in the classroom, to check whether the methodologies used promote meaningful and lasting learning.

Table 12. Post-test II descriptives (Variable: Study group. Control group vs. Experimental group).

Post-Test II	n	Mean	Std. Deviation	Std. Error Mean
Experimental Group	144	7.34	1.838	0.157
Control Group	112	5.91	1.985	0.187

An inferential analysis was carried out to see if there were statistically significant differences in the results of post-test II depending on the study group variable. Table 13 shows the results of the Student's t-test obtained.

Table 13. Student's t-test in the post-test II (Variable: Study group. Experimental Group vs. Control Group).

t	df	Sig. (2-Tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
					Lower	Upper
−5.861	246	<0.001 *	−1.42551	0.24321	−1.90454	−0.94647

* Sig. < 0.05.

The results shown in Table 13 reveal that there are statistically significant differences (Sig. < 0.001) between the mean scores obtained by the two study samples. Specifically, a mean difference of 1.42 points out of ten is observed in favor of the experimental group. To check the effect size of the statistically significant differences found in post-test II of the control and experimental groups, we calculated Cohen's delta value, represented by d [54]. Specifically, a value of d = 1.89 was obtained. This result reveals an effect size classified as high in the literature. These results seem to indicate that the intervention based on the STEM workshops has been more effective from a didactic point of view than the methodology used with the control group, suggesting the agreement of Hypothesis 3 proposed in the research (Hypothesis 3: The implementation of STEM workshops facilitates meaningful and long-term learning in primary school students in the face of an expository academic intervention in the science classroom). However, in order to firmly confirm this, and to validate the long-term teaching effectiveness of the implemented STEM workshops, it is convenient to show the level of knowledge acquired by students in the three tests: pre-test, post-test I and post-test II in both the control and experimental groups. Tables 14 and 15 show the inferential analysis made from the statistical One-way ANOVA with post-hoc Tukey HSD Test.

Table 14 indicates that there are statistically significant differences between the pre-test, post-test I and post-test II questionnaires in both the control and experimental groups. Table 15 shows among which questionnaires these differences exist in both the control and experimental groups.

Table 14. One-way ANOVA.

		Sum of Squares	df	Mean Square	F	Sig.
EG	Between Groups	152.986	2	76.493	25.437	<0.001 *
	Within Groups	1163.748	387	3.007		
	Total	1316.733	389			
CG	Between Groups	140.753	2	70.377	18.742	<0.001 *
	Within Groups	1250.409	333	3.755		
	Total	1391.162	335			

* Sig. < 0.05.

Table 15. Tukey HSD test.

	(I) Exam Type	(J) Exam Type	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
CG	PRE-TEST	POST-TEST I	−1.39782 *	0.25895	<0.000 *	−2.0074	−0.7882
	POST-TEST I	POST-TEST II	1.34673 *	0.25895	<0.000 *	0.7371	1.9563
	PRE-TEST	POST-TEST II	−0.05109	0.25895	0.979	−0.6607	0.5585
EG	PRE-TEST	POST-TEST I	−1.55730 *	0.21844	<0.000 *	−2.0712	−1.0434
	POST-TEST I	POST-TEST II	0.75110 *	0.20953	0.001 *	0.2581	1.2441
	PRE-TEST	POST-TEST II	−0.80620 *	0.21917	0.001 *	−1.3219	−0.2906

* Sig. < 0.05.

With respect to the control group, the statistically significant differences (Sig. < 0.001) are between pre-test and post-test I (in favor of post-test I) and between post-test I and post-test II (in favor of post-test I). In other words, the student improves his initial level of knowledge after the intervention (in the short-term) but forgets the contents over time (in the long-term). If we compare the results of post-test II with the initial level of knowledge (pre-test), we can see that there are no statistically significant differences between the average scores of these two questionnaires in the control group (Sig. = 0.979). These results reveal that these students return to their initial level of knowledge and, therefore, it is accepted that these students have not adequately retained the contents over time due to rote learning.

However, if we look at Tables 14 and 15 concerning the experimental group, we can see that there are statistically significant differences in all cases. Contrary to the control group, the results of the comparison between the post-test II and the pre-test carried out by the experimental group show that these students have preserved the memory of the contents in the long-term, since the average grade reached in the post-test II has been higher than the one obtained in the initial pre-test, finding statistically significant differences between the average grades of these two questionnaires carried out by said experimental sample (Sig. = 0.001). These results allow us to confirm the Hypothesis 3 stated in the research "The implementation of STEM workshops facilitates meaningful, long-term learning for primary school students compared to expository academic intervention in the science classroom".

The above data confirm the importance of using active practical methodologies that include student hands-on workshops in order to achieve meaningful and long-term learning of STEM content worked on in the classroom. Likewise, these results complement previous research which shows that hands-on learning is a way of enhancing meaningful learning because it favors mental constructions of more abstract contents [15,42,55–58].

Finally, as in the previous sections, Table 16 shows the descriptive statistics by gender and Table 17 shows the inferential analysis carried out to check whether there are statistically significant differences between the average scores obtained according to this variable.

Table 16. Post-test II descriptives (Variable: Gender. Women vs. Men).

Gender	Mean	Std. Deviation	Std. Error Mean
Men	6.6082	2.09684	0.19639
Women	6.7724	1.97737	0.17082

Table 17. Student's t-test in the post-test II (Variable: Gender. Women vs. Men).

t	df	Sig. (2-Tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
					Lower	Upper
−0.634	246	0.527	−0.16420	0.25905	−0.67444	0.34604

If we look at Table 16, the descriptive analysis reveals again that girls show slightly better cognitive domain in the contents under study than boys, but the inferential analysis shown in Table 17 confirms that this mean difference is not statistically significant (Sig. = 0.527). These results allow us to finally reject the Hypothesis 6 proposed in the research "Participating male students show a higher level of knowledge of the selected STEM content than participating female students".

3.4. Results of the Emotional and Attitudinal Analysis

In this section, we present the data referred to the emotional and attitudinal analysis of the participating sample with respect to the intervention received in each case. Table 18 shows the results obtained in the different emotions analyzed, distinguishing by study group.

Table 18. Percentage of students who have felt the emotion.

Emotions	Control Group %	Experimental Group %
Curiosity	70.5	78.3
Fun	59.8	89.9
Confidence	40.2	52.2
Satisfaction	36.6	60.9
Disgust	4.5	4.3
Boredom	18.8	3.6
Worry	5.4	18.8
Anger	6.3	8.7

As can be seen in Table 18, the analysis of emotions determined that the majority of primary school students show positive emotions when faced with the learning of STEM content, as other authors have pointed out in previous research [15,42,59,60]. However, it was observed that the experimental group showed a greater proportion of positive emotions than the control group, and this difference was statistically significant (Sig. < 0.05) in positive emotions such as fun, satisfaction or confidence.

At the same time, it seems logical to find high values in the emotion of curiosity in both groups, since the simple fact of receiving a class session from a person outside the educational circle draws attention and generates uncertainty and curiosity. This is verified in the qualitative analysis of the data, where statements are obtained from students belonging to the control group such as "I was curious when the new teacher arrived" or "Because I didn't know what I was going to do". Likewise, a large part of the participating students showed curiosity when some contents that were new to them were introduced in the session, such as Newton's laws ("With Newton's laws", "With the explanation of the laws" or "Learning the laws" are some of the statements made by some subjects of the control group and "With the Newton's" and "To know what Newton's laws were about" are some of the statements made by some students of the experimental group. However, this same group of students also expressed curiosity about the model that they were going to make, finding arguments such as the following: "When we were shown the car we were going to make" or "To know how the car was made". Curiosity is an engine that helps generate intrinsic motivation, as opposed to repetitive, mechanical or memorized tasks [61]. Providing learning strategies based on curiosity can increase students' dedication to work and deepen their scientific literacy [62].

On the other hand, it is evident that 90% of the students in the experimental group showed the emotion of fun during the intervention compared to 60% of the students in the control group. As several authors indicate, manipulative activities not only favor learning, but also make the teaching-learning experience fun for both students and teachers [15,33,63]. In reference to the fun emotion, some comments extracted from the experimental group were "When the car was moving", "When I was making the car with my classmates" and "When we were measuring the distance our car travelled in the corridor".

On the other hand, it is observed that the students of the experimental group show more emotions such as confidence or satisfaction for having been immersed in the elaboration of a model and having made it adequately. In this situation, the students of the control group have not been involved and therefore, most of these students have not experienced moments in which they have manifested such emotions.

Regarding negative emotions, it should be noted that emotions such as boredom contribute to the progressive loss of attention [64]. Considering this statement, it should be noted that almost 20% of the students in the control group indicated that they had experienced boredom at some point during the session. This may be due to the fact that the academic-expositional methodology applied to this group did not promote a relationship between the content and daily life, and did not encourage reasoning and active participation by the students as the STEM workshop did with the experimental group. For this reason, it is necessary to consider more active and practical learning strategies in the classroom, since, as some studies point out [13], negative emotions are more often expressed during theoretical learning, and positive emotions through practical learning.

On the other hand, it seems logical that up to 19% of the students in the experimental group expressed greater concern than those in the control group. As observed in the qualitative analysis of the data, the latter were under pressure of not making the model well and that, for this reason, it could not work in the end. Opinions such as "When the car didn't work at first", "In case the car didn't work" or "Because we didn't know how to place the balloon properly" were some of the proposals made by the experimental group regarding the emotion of concern. The same thing happened with the emotion of anger. 8% of the experimental group expressed this emotion when they encountered obstacles during the STEM workshop. On the part of the control group, some students indicated that they felt this emotion because they had received a mere explanation of the scientific content dealt with.

Based on the results exposed in the analyzed emotional variables, we can accept the Hypothesis 4 proposed in the research "The implementation of the STEM workshop with the experimental group mainly generates positive emotions in primary education students compared to the transmission-reception methodology applied with the control group".

On the other hand, the attitudes of the students towards the intervention carried out were analyzed. Ten questions were posed to each group of students, adapted to the session received. However, in both cases, the questions were related to the acquired learning, the interest shown, the methodological preferences and the self-efficacy of the students. Students had to choose between two options (YES and NO) based on their considerations. The results are shown in Table 19.

Table 19. Analysis of student attitudes (percentage of Yes).

ITEM	GC	GE
	%	%
1. Did you like the workshop/class you attended?	88.4	99.3
2. Have you learned the contents explained?	87.5	99.3
3. Would you have liked to make a model related to the contents explained? (CG) Would you like to do more of these activities in science and math classes? (EG)	73.2	97.1
4. Do you think it's easier to learn science content by doing hands-on activities?	80.4	86.2
5. Would you have learned better the contents you saw today by making a model? (CG) Would you have learned the contents without doing the practical workshop? (EG)	50.0	36.2
6. Do you think you would remember the contents you have learned better if you had made a model? (CG) Do you think you will remember the contents you have learned more easily thanks to the practical workshop? (EG)	43.8	95.7
7. Have you learned any content you didn't know about?	82.1	91.3
8. Do you need another class to better understand the contents? (CG) Did you need help with the action-reaction car? (EG)	22.3	66.7
9. Did you find it difficult to learn the contents? (CG) Did you find it difficult to perform the action-reaction car? (EG)	23.2	15.2
10. Could you make a model of your own related to the contents worked on? (CG) Could you make the model of the action-reaction car by yourself and without help? (EG)	46.4	68.1

The results shown in Table 19 indicate that the students generally show interest in the teaching-learning of scientific-technological contents, since more than 85% of students in both groups expressed interest in the session received (statement 1) and more than 80%, in both groups, indicated having learned new concepts during the intervention (statement 7); concepts that, in addition, were not difficult to understand (statement 8). However, although in both cases, the students consider what they have learned, it is interesting to highlight that practically the totality of the experimental sample indicated that they had learned the contents compared to 87% of the students in the control group (statement 2).

In reference to methodological issues, it is noted that there is a strong preference for hands-on learning methods by the participating sample. 73% of students in the control group indicated that they would have liked to make a model related to the contents explained and more than 95% in the experimental group would like to make more models in the science and mathematics classes (statement 3). These results are linked to those obtained in statement 4, where it is observed that more than 80% of the students, in both groups, consider that the practical activities facilitate the learning of the contents, but they can also be related to the contributions of the experimental group in statement 6 that indicate that they will remember the contents better thanks to the workshop. Likewise, 50% of the students in the control group would have liked to make a supplementary model to the contents explained in the intervention (statement 5). Finally, the information extracted on the level of self-efficacy suggests that there are great differences between groups, since almost 70% of the experimental group considered themselves to be capable of making models only as opposed to 46% of the control group. Evidently, this is due to the technology and engineering skills and knowledge incorporated in the STEM workshop and acquired by the students in the experimental group.

The previous results allow us to accept the Hypothesis 5 proposed in the research "The implementation of the STEM workshop with the experimental group mainly generates positive attitudes in the primary education students compared to the transmission-reception methodology applied with the control group".

4. Discussion

After analyzing the data, it is assumed that students in the last levels of primary school show problems in remembering content about forces and movement that they have already worked on in previous years. This leads to the formation of conceptual errors that may have negative repercussions on the future learning of these contents [65]. In this line, we agree with other authors [2], that the main orientation of educational processes is usually based exclusively on the development of knowledge about concepts, principles and laws of scientific disciplines, forgetting or relegating other important areas of training.

In contrast, the data confirm that the application of constructivist and constructionist approaches has a positive effect on increasing the interest and involvement of participants [66]. The inclusion of simple experiences in the classroom to work on STEM content greatly favors learning and the consolidation of this content in the long-term [15,42], as can be seen from the results obtained in post-test II. In this sense, our results coincide with previous research linking hands-on activities with increased student knowledge and academic performance in STEM subjects [23,67,68]. In order to learn about a phenomenon in nature, it is necessary to experiment and explore how it manifests and, to do so, students need to become fully and actively involved with the phenomenon in order to understand it in depth [69]. Furthermore, the results found suggest that the use of pedagogical practices based on cooperative and authentic learning fosters a timely work and learning environment since the group work environment emphasizes student effort, improvement and mastery and helps students not only to feel safe but also to be competent in STEM [70].

Regarding gender differences, many studies show that girls tend to have a lower cognitive level in science than boys, regardless of their type of school and their age. They also suggest that boys show greater self-confidence in dealing with scientific problems than girls and, therefore, that the cognitive level acquired is higher in males than in females [71,72]. However, this study supports the opposite view, as it was found that girls showed a better domain of the contents discussed in all the cases analyzed. However, this cognitive difference is not statistically significant according to the data.

Furthermore, we agree with other researchers [73] that it is possible that participation in STEM activities may have a positive effect on student self-efficacy in STEM or even in a specific discipline related to STEM content, and therefore, continued participation in STEM activities will further enhance self-efficacy in these fields. Moreover, literature shows that self-efficacy predicts both academic and career-related choices [74], and therefore, improving self-efficacy within a specific content domain may increase the likelihood of choosing a career associated with that domain [75,76].

With respect to the affective variable, we agree with the latest contributions of neuroeducation that it is desirable for teachers at any educational level to pay attention to the emotions that are generated during the teaching-learning process [12,13]. After participating in the workshop, the students in the experimental group have developed an understanding of what science is and of the importance of scientific literacy, but they have also increased their motivation to study science and technology in the classroom [62]. Thus, it is necessary that the activities proposed to the students awaken their curiosity because students who are curious will focus their attention on the object that arouses it, improving their predisposition to learn and their desire to learn [77]. However, although it is essential to influence academic emotions through the choice of learning strategies because they can have an important effect on learning [78], we agree with other authors [79,80] that the simple experience of positive emotions is not enough to trigger interest and situational engagement. Enjoyment must be explicitly connected to the content of directed learning.

Teaching actions must take into account differences in the way learning is approached in order to adjust their action plan and thus optimize the learning of all students [81,82], but given the high number of scientific and technological contents that currently exist, the task of selecting them becomes increasingly complicated. However, in order to fulfil its function of helping the process of development and socialization of students, school education must consider the intrinsically constructive nature of the human psyche and build on it [83].

STEM teaching interventions aim to contribute to the improvement of science and technology education from an early age by providing teaching methodologies that deliver quality education. The STEM workshops were carried out with recycled material, thus promoting responsible consumption among primary school students. In this way, it is recognized that both scientific and technological knowledge should be part of citizenship worldwide, promoting sustainable attitudes and behaviors [84]. This type of methodology, which influences not only the cognitive but also the emotional domain of students, can contribute to the objectives of sustainable development within the educational context. In this line, the Sustainable Development Goals decided upon by the United Nations include an objective (SDG 4 "Quality education") focused on the acquisition by students of the knowledge and skills needed to promote sustainable development [85].

Today's education requires knowing what to do with information, that is, how to analyze it, cooperate with others to summarize it, apply it and communicate the results [86]. Therefore, quality education is no longer based primarily on the acquisition of knowledge but requires the development of skills and attitudes that ensure the proper use of information in accordance with the context. In this sense, we agree with [87] that promoting scientific literacy through STEM programs includes the development of skills that actively engage students in solving current societal problems such as changing stereotypes in education [88] or improving specific behaviors related to sustainability.

Today's social needs require that education be directed towards the development of sustainability and social justice [89]. However, working on these types of problems in the classroom to promote critical thinking, democratic values and the active search for solutions are aspects that imply the mastery of the necessary scientific knowledge [90]. Education for sustainability implies a different vision of the curriculum, pedagogy, organizational change and educational policies [91]. In this sense, we agree with other researchers [92] that the best way to develop these competencies in sustainability is through interdisciplinary work on scientific subjects. Consequently, STEM skills are part of the competence field required by 21st century citizens because they are oriented to develop a range of key competences that are essential for living and working in our society.

This research shows evidence that student learning can be improved if we incorporate a teaching style that connects scientific and technological content in the classroom [93,94]. In this sense, we consider that STEM programs help students to develop a better understanding of scientific and technological knowledge based on the results presented. Supporting communicative methodologies with STEM programs produces positive changes in students' cognitive and emotional development, fostering active participation and autonomy of students in science classrooms [42].

Likewise, there seems to be a high degree of agreement between the results of this study and the literature regarding the need to choose a common and reduced core of knowledge, of great intrinsic and educational value, related to the lives of students, that can be applied and be useful to them [19,20,95]. In this line, it is concluded that STEM teaching approaches offer students the opportunity to participate in practical and manipulative lessons that have a positive effect on students' knowledge, interests and skills, as well as on their decision to continue learning science and technology together.

5. Conclusions

To enhance long-term learning, it is important to use learning resources in a meaningful way, that is, connected and integrated within the thematic structure. Active methodologies are recognized as facilitating and promoting strategies for learning and critical thinking because they facilitate the transmission of messages and promote communication among students by relying on the application of participatory mechanisms. In this line, the contribution of the STEM workshops in the development of scientific-technological learning could be related to the stimulation of three important and significant processes that are generated in a coordinated way in this participatory field, namely, cognitive, attitudinal and socializing processes. The STEM workshops aim to enable students to develop epistemic, procedural and contextual knowledge and are geared towards developing the ability to act and acquire skills in relation to what is being learned. However, this educational paradigm is not only intended to develop intellectual skills, but also to encourage students to act in the experimental design itself and in the discussion about it, thus enhancing their ability to formulate hypotheses and to reason about them and to establish connections between some contents and others, thus causing an improvement in the scientific-technological vocations and in the students' attitudes towards the STEM areas.

Based on the results of the study, we believe that, in order to maintain attitudes and vocations throughout the educational process, it is necessary to rethink the possibility of applying this integration of content throughout primary education but also during compulsory secondary education, the baccalaureate and higher education, taking into account the comprehensive and functional nature that science teaching should have at those stages. However, the work of developing competences in others forces teachers to review their own competences. We consider the role of the teachers to be indispensable, since through their training and attitude they will be able to offer their students learning in a more playful and effective way. In this sense, strengthening the attention paid to specific didactics in general, and to the didactics of experimental sciences in particular, in permanent teacher training plans, becomes a challenge for education institutions to define the levels of achievement of competences and the processes of training and updating of future teachers in order to improve their knowledge, skills and attitudes to achieve greater efficiency in their professional practice [96].

Finally, we suggest that future studies explore the experiences of high school students in STEM workshops designed for these levels and further investigate the factors that may influence students' decisions to choose one educational path over another. Likewise, it would be interesting to assess the training of active teachers in order to gather information about the skills that should be strengthened in the training itineraries of these groups. In the meantime, the results of this study will be added to the growing literature on STEM learning environments and their influence on the cognitive and affective dimensions of students.

Author Contributions: Conceptualization, all authors; methodology, all authors; validation, all authors; formal analysis, M.M.-N. and G.M.-B.; investigation, all authors; resources, all authors; data curation, M.M.-N. and G.M.-B.; writing—original draft preparation, all authors; writing—review and editing, all authors; visualization, all authors; supervision, all authors; project administration, G.M.-B.; funding acquisition, G.M.-B. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by Junta de Extremadura/Fondo Europeo de Desarrollo Regional, Research Project IB16068, Agencia Estatal de Investigación/Fondo Europeo de Desarrollo Regional, Research Project EDU2016-77007-R and Junta de Extremadura/Fondo Europeo de Desarrollo Regional, Grant GR18004.

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

References

1. Harlen, W. Evaluar la alfabetización científica en el programa de la OECD para la evaluación internacional de estudiantes (PISA). *Enseñanza Cienc.* **2002**, *20*, 209–216.
2. Banet, E. Finalidades de la educación científica en secundaria: Opinión del profesorado sobre la situación actual. *Enseñanza Cienc.* **2007**, *25*, 5–20.
3. Furió, C.; Vilches, A.; Guisasola, J.; Romo, V. Finalidades de la enseñanza de las ciencias en la Secundaria Obligatoria. ¿Alfabetización científica o preparación propedéutica? *Enseñanza Cienc.* **2001**, *19*, 365–376.
4. Martin, C.; Prieto, T.; Jiménez, M.A. Tendencias del profesorado de ciencias en formación inicial sobre las estrategias metodológicas en la enseñanza de las ciencias. Estudio de un caso en Málaga. *Enseñanza Cienc.* **2015**, *33*, 167–184.
5. Hodson, D. Time for action: Science education for an alternative future. *Int. J. Sci. Educ.* **2003**, *25*, 645–670. [CrossRef]
6. Fadzil, H.M.; Saat, R.M. Enhancing STEM Education during School Transition: Bridging the Gap in Science Manipulative Skills. *Eurasia J. Math. Sci. Technol. Ed.* **2014**, *10*, 209–218.
7. OCDE. *PISA 2015: Resultados Clave*; OECD: Paris, France, 2016.
8. OECD. *The Future of Education and Skills: Education 2030*; OECD: Paris, France, 2018.
9. Tai, R.H.; Liu, C.Q.; Maltese, A.V.; Fan, X. Planning early for carrers in science. *Science* **2006**, *312*, 1143–1145. [CrossRef]
10. Gardner, H. *Inteligencias Múltiples, la Teoría en la Práctica*; Ediciones Paidós: Barcelona, Spain, 1995.
11. Goleman, D. *La Inteligencia Emocional*; Javier Vergara: Santa Fe de Bogotá, Colombia, 1996.
12. Osborne, J.; Dillon, J. *Science Education in Europe: Critical Reflections*; The Nuffield Foundation: London, UK, 2008.
13. Mellado, V.; Borrachero, A.B.; Brígido, M.; Melo, L.V.; Dávila, M.A.; Cañada, F.; Conde, M.C.; Costillo, E.; Cubero, J.; Esteban, R.; et al. Las emociones en la enseñanza de las ciencias. *Enseñanza Cienc.* **2014**, *32*, 11–36.
14. Tobin, K. Reproducir y transformar la didáctica de las ciencias en un ambiente colaborativo. *Enseñanza Cienc.* **2010**, *28*, 301–314.
15. Martínez, G.; Naranjo, F.L.; Mateos, M.; Sánchez, J. Recreational Experiences for Teaching Basic Scientific Concepts in Primary Education: The Case of Density and Pressure. *Eurasia J. Math. Sci. Technol. Ed.* **2018**, *14*, 1–16.
16. Perry-Deborah, L. *What Makes Learning Fun? Principles for the Design of Intrinsically Motivating Museun Exhibits*; AltaMira Press: Chicago, IL, USA, 2012.
17. González-Peiteado, M.; Pino-Juste, M. Los estilos de enseñanza: Construyendo puentes para transitar las diferencias individuales del alumnado. Teaching styles: Building bridges to approach individual differences of students. *Rev. Complut. Educ.* **2016**, *27*, 1175–1191. [CrossRef]
18. López-Quintero, J.L.; Varo, M.; Laguna, A.M.; Pontes, A. Opinions on “Classroom Response System” by first-year engineering students. *Procedia Soc. Behav. Sci.* **2016**, *228*, 183–189. [CrossRef]
19. Couso, D.; Jiménez, M.P.; López-Ruiz, J.; Mans, C.; Rodríguez, C.; Rodríguez, J.M.; Sanmartí, N. *Informe Enciende: Enseñanza de las Ciencias en la Didáctica Escolar Para Edades Tempranas en España*; COSCE: Madrid, Spain, 2011.
20. Rocard, M.; Csermely, P.; Jorde, D.; Lenzen, D.; Walwerg-Henriksson, H.; Hemmo, V. *Science Education Now: A Renewed Pedagogy for the Future of Europe*; European Commission Community Research: Brussels, Belgium, 2007.
21. Vaval, L.; Bowers, A.J.; Snodgrass Rangel, V. Identifying a typology of high schools based on their orientation toward STEM: A latent class analysis of HSLS: 09. *Sci. Educ.* **2019**, *103*, 1151–1175. [CrossRef]
22. Sanders, M.E. STEM, STEM education, STEMmania. *Technol. Teach.* **2008**, *68*, 20–26.

23. Bybee, R.W. Achieving Scientific Literacy: Strategies for Insuring that Free-Choice Science Education Complements National Formal Science Education Efforts. In *Free-Choice Science Education: How We Learn Science Outside of School*; John, H.F., Ed.; Teachers College Press: New York, NY, USA, 2001; pp. 44–63.
24. Kelley, T.R.; Knowles, J.G. A conceptual framework for integrated STEM education. *Int. J. STEM Educ.* **2016**, *3*, 1–11. [CrossRef]
25. Wiswall, M.; Stiefel, L.; Schwartz, A.E.; Boccardo, J. Does attending a STEM high school improve student performance? Evidence from New York City. *Econom. Educ. Rev.* **2014**, *40*, 93–105. [CrossRef]
26. Means, B.; Wang, H.; Young, V.; Peters, V.L.; Lynch, S.J. STEM—focused high schools as a strategy for enhancing readiness for postsecondary STEM programs. *J. Res. Sci. Teach.* **2016**, *53*, 709–736. [CrossRef]
27. Judson, E. Effects of transferring to STEM-focused charter and magnet schools on student achievement. *J. Educ. Res.* **2014**, *107*, 255–266. [CrossRef]
28. España, E.; Prieto, T. Los problemas socio-científicos como contexto para la enseñanza y el aprendizaje de las ciencias. *Investig. Esc.* **2010**, *71*, 17–24.
29. Haney, J.J.; McArthur, J. Four case studies of prospective science teachers'beliefs concerning constructivist teaching practices. *Sci. Educ.* **2002**, *86*, 783–802. [CrossRef]
30. Zembylas, M. Emotional ecology: The intersection of emotional knowledge and pedagogical content knowledge in teaching. *Teach. Teach. Educ.* **2007**, *23*, 355–367. [CrossRef]
31. Eldar, E.; Rutledge, R.; Dolan, R.; Niv, Y. Mood as representation of momentum. *Trends Cogn. Sci.* **2016**, *20*, 15–24. [CrossRef] [PubMed]
32. Marcos-Merino, J.M. Análisis de las relaciones emociones-aprendizaje de maestros en formación inicial con una práctica activa de Biología. *REurEDC* **2019**, *16*, 1–14. [CrossRef]
33. Bellocchi, A.; Ritchie, S.M.; Tobin, K.; King, D.; Sandhu, M.; Henderson, S. Emotional climate and high-quality learning experiences in science teacher education. *J. Res. Sci. Teach.* **2014**, *51*, 1301–1325. [CrossRef]
34. English, L.D. STEM education K-12: Perspectives on integration. *Int. J. STEM Educ.* **2016**, *3*, 1–8. [CrossRef]
35. Martínez, G.; Naranjo, F.L.; Pérez, Á.L.; Suero, M.I.; Pardo, P.J. Meaningful learning theory in science education: Just another pedagogical trend? *J. Sci. Educ.* **2017**, *18*, 19–23.
36. Morales-Maure, L.; García-Marimón, O.; Torres-Rodríguez, A.; Lebrija-Trejos, A. Habilidades cognitivas a través de la estrategia de aprendizaje cooperativo y perfeccionamiento epistemológico en Matemática de estudiantes de primer año de universidad. *Form. Univ.* **2018**, *11*, 45–56. [CrossRef]
37. Garritz, A.; Ortega-Villar, N.A. El Aspecto Afectivo en la Enseñanza Universitaria. Cómo Cinco Profesores Enseñan el Enlace Químico en la Materia Condensada. In *Las Emociones en la Enseñanza y el Aprendizaje de las Ciencias y las Matemáticas*; Mellado, V., Blanco, L.J., Borrachero, A.B., Cárdenas, Y.J.A., Eds.; UEX-DEPROFE: Badajoz, Spain, 2013; pp. 277–304.
38. Damasio, A. *Y el Cerebro Creó al Hombre*; Destino: Barcelona, Spain, 2010.
39. Mora, F. El Reloj de la Sabiduría. In *Tiempos y Espacios en el Cerebro Humano*; Alianza Editorial: Madrid, Spain, 2008.
40. White, G. Emotions Inside Out: The Anthropology of Affect. In *Handbook of Emotions*; Lewis, M., Haviland, Y.J., Eds.; Guildford Press: New York, NY, USA, 1993.
41. Lasky, S. The Cultural and Emotional Politics of Teacher—Parent Interactions. *Teach. Teach. Educ.* **2000**, *16*, 843–860. [CrossRef]
42. Martínez, G.; Mateos, M.; Naranjo, F.L. Implementation and Didactic Validation of STEM Experiences in Primary Education: Analysis of the Cognitive and Affective Dimension. In *Theorizing STEM Education in the 21st Century*; IntechOpen: London, UK, 2019.
43. Mateos, M.; Martínez, G.; Naranjo, F.L. Análisis Cognitivo y Emocional Hacia Competencias Científico-Tecnológicas en el Alumnado de 6° de Educación Primaria. In *Conectando Pilares Para la Educación*; Alicia, B.C., Ed.; Global Knowledge Academics: Madrid, Spain, 2019; pp. 113–124.
44. Ding, L.; Chabay, R.; Sherwood, B.; Beichner, R. Evaluating an electricity and magnetism assessment tool: Brief electricity and magnetism assessment. *Phys. Rev. Phys. Educ. Res.* **2006**, *2*, 1–7. [CrossRef]
45. McColgan, M.W.; Finn, R.A.; Broder, D.L.; Hassel, G.E. Assessing students' conceptual knowledge of electricity and magnetism. *Phys. Rev. Phys. Educ. Res.* **2017**, *13*, 1–19. [CrossRef]
46. Barbosa, L.H. Construcción, validación y calibración de un instrumento de medida del aprendizaje: Test de Ley de Bernoulli. *Rev. Educ. Ing.* **2013**, *8*, 24–37.

47. Maltese, A.V.; Tai, R.H. Pipeline persistence: Examining the association of educational experiences with earned degrees in STEM among US students. *Sci. Educ.* **2011**, *95*, 877–907. [CrossRef]
48. Ausubel, N.; Novak, J. *Hanesian, Psicología Educative: Un Punto de Vista Cognoscitivo*, 2nd ed.; Editorial Trillas: Mexico City, Mexico, 1983.
49. Driver, R. Psicología cognoscitiva y esquemas conceptuales de los alumnos. *Enseñanza Cienc.* **1986**, *4*, 3–15.
50. Bello, S. Ideas previas y cambio conceptual. *Educ. Química* **2004**, *15*, 61–67.
51. Mora, C.; Herrera, D. Una revisión sobre ideas previas del concepto de fuerza. *Latin Am. J. Phys. Educ.* **2009**, *3*, 72–86.
52. Morgan, C.; Isaac, J.D.; Sansone, C. The role of interest in understanding the career choices of female and male college students. *Sex Roles* **2001**, *44*, 295–320. [CrossRef]
53. Miyake, A.; Kost-Smith, L.E.; Finkelstein, N.D.; Pollock, S.J.; Cohen, G.L.; Ito, T.A. Reducing the gender achievement gap in college science: A classroom study of values affirmation. *Science* **2010**, *330*, 1234–1237. [CrossRef]
54. Cohen, J. *Statistical Power Analysis for the Behavioral Sciences*, 2nd ed.; Erlbaum: Hillsdale, NJ, USA, 1988.
55. McCombs, B.L. What do we know about learners and learning? The learner-centered framework: Bringing the educational system into balance. *Educ. Horiz.* **2001**, *79*, 182–193.
56. McAlpine, L. Designing learning as well as teaching. A research-based model for instruction that emphasizes learner practice. *Active Learn. High. Educ.* **2004**, *5*, 119–134. [CrossRef]
57. Wade-Jaimes, K.; Demir, K.; Qureshi, A. Modeling strategies enhanced by metacognitive tools in high school physics to support student conceptual trajectories and understanding of electricity. *Sci. Educ.* **2018**, *102*, 711–743. [CrossRef]
58. Greca, I.M.; Moreira, M.A. Mental, physical, and mathematical models in the teaching and learning of physics. *Sci. Educ.* **2002**, *86*, 106–121. [CrossRef]
59. Mateos, M.; Martínez, G.; Naranjo, F.L. Analysis of Emotions and Methodological Preferences in Primary Education Students. In Proceedings of the INTED 2018, Valencia, Spain, 5–7 March 2018; pp. 2440–2449.
60. Mateos, M.; Martínez, G.; Naranjo, F.L. Comparación de las emociones, actitudes y niveles de autoeficacia ante áreas STEM entre diferentes etapas educativas. *Eur. J. Educ. Psychol.* **2019**, *13*, 251–267. [CrossRef]
61. Otero. Emociones, sentimientos y razonamientos en Didáctica de las Ciencias. *Rev. Electrónica Investig. Educ. Cienc.* **2006**, *1*, 24–53.
62. Vázquez, A.; Manassero, M.A. El declive de las actitudes hacia la ciencia de los estudiantes: Un indicador inquietante para la educación científica. *REurEDC* **2008**, *5*, 274–292. [CrossRef]
63. García, R. Ciencia recreativa: Un recurso didáctico para enseñar deleitando. *REurEDC* **2011**, 370–392. [CrossRef]
64. Gómez-Ochoa de Alda, J.A.; Marcos-Merino, J.M.; Méndez-Gómez, F.J.; Mellado, V.; Esteban-Gallego, M.R. Emociones académicas y aprendizaje de biología, una asocia ción duradera. *Enseñanza Cienc.* **2019**, *3*, 43–61.
65. Carrascosa, J.; Gil, D. Concepciones alternativas en mecánica. Dinámica: Las fuerzas como causa del movimiento. Selección de cuestiones elaboradas para su detección y tratamiento. *Enseñanza Cienc.* **1992**, *10*, 314–328.
66. Abrahams, I.; Millar, R. Does practical work really work? A study of the effectiveness of practical work as a teaching and learning method in school science. *Int. J. Sci. Educ.* **2008**, *30*, 1945–1969. [CrossRef]
67. Bell, P.; Lewenstein, B.; Shouse, A.W.; Feder, M.A. *Learning Science in Informal Environments: People, Places, and Pursuits*; The National Academies Press: Washington, DC, USA, 2009.
68. Eccles, J.S.; Barber, B.L. Student council, volunteering, basketball, or marching band what kind of extracurricular involvement matters? *J. Adolesc. Res.* **1999**, *14*, 10–43. [CrossRef]
69. Gellon, G.; Rosenvasser-Feher, E.; Furman, M.; Golombek, D. *La Ciencia en el Aula. Lo Que Nos Dice la Ciencia Sobre Cómo Enseñarla*; Editorial Paidos: Buenos Aires, Argentina, 2005.
70. Zollman, A. Learning for STEM literacy: STEM literacy for learning. *Sch. Sci. Math.* **2012**, *112*, 12–19. [CrossRef]
71. Buccheri, G.; Gürber, N.A.; Brühwiler, C. The impact of gender on interest in science topics and the choice of scientific and technical vocations. *Int. J. Sci. Educ.* **2011**, *33*, 159–178. [CrossRef]
72. Oppermann, E.; Brunner, M.; Eccles, J.S.; Anders, Y. Uncovering young children's motivational beliefs about learning science. *J. Res. Sci. Teach.* **2018**, *55*, 399–421. [CrossRef]

73. Miller, K.; Sonnert, G.; Sadler, P. The influence of students' participation in STEM competitions on their interest in STEM careers. *Int. J. Sci. Educ.* **2018**, *8*, 95–114. [CrossRef]
74. Lent, R.W.; Brown, S.D.; Hackett, G. Toward a unifying social cognitive theory of career and academic interest, choice, and performance. *J. Vocat. Behav.* **1994**, *45*, 79–122. [CrossRef]
75. National Research Council. *Successful K-12 STEM Education: Identifying Effective Approaches in Science, Technology, Engineering, and Mathematics*; The National Academies Press: Washington, DC, USA, 2011.
76. Subotnik, R.F.; Tai, R.H.; Almarode, J.; Crowe, E. What are the value added contributions of selective secondary schools of mathematics, science and technology?—Preliminary analyses from a U.S. national research study. *Talent Develop. Excell.* **2013**, *5*, 87–97.
77. Mora, F. *Neuroeducación*; Alianza Editorial: Barcelona, Spain, 2013.
78. Mega, C.; Ronconi, L.; De Beni, R. What makes a good student? How emotions, self-regulated learning, and motivation contribute to academic achievement. *J. Educ. Psychol.* **2014**, *106*, 121–131. [CrossRef]
79. Ainley, M.; Ainley, J. Student Engagement with Science in Early Adolescence: The Contribution of Enjoyment to Students' Continuing Interest in Learning about Science. *Contemp. Educ. Psychol.* **2011**, *36*, 4–12. [CrossRef]
80. Hidi, S.; Renninger, K.A. The Four-Phase Model of Interest Development. *Educ. Psychol.* **2006**, *41*, 111–127.
81. Alonso, C. Estilos de aprendizaje. Presente y futuro. *Rev. Estilos Aprendiz.* **2008**, *1*, 4–15.
82. López-Aguado, M. Estilos de aprendizaje. Diferencias por género, curso y titulación. *Rev. Estilos Aprendiz.* **2011**, *8*, 109–134.
83. Coll, C. Constructivismo y educación escolar: Ni hablamos siempre de los mismo ni lo hacemos siempre desde la misma perspectiva epistemológica. *UB J. Psychol.* **1996**, *69*, 153–178.
84. Gutiérrez, J.; Calvo, S.; Benayas, J. Educación para el desarrollo sostenible: Evaluación de retos y oportunidades del decenio 2005–2014. *Rev. Iberoam. Educ.* **2006**, *40*, 25–69.
85. UNESCO. *Sustainable Development Goals (Online)*; UNESCO: Paris, France, 2015; Available online: http://en.unesco.org/sdgs (accessed on 15 February 2020).
86. Laurie, R.; Nonoyama-Tarumi, Y.; Mckeown, R.; Hopkins, C. Contributions of education for sustainable development (ESD) to quality education: A synthesis of research. *J. Educ. Sust. Dev.* **2016**, *10*, 226–242. [CrossRef]
87. Ull, M.Á.U. Competencias para la sostenibilidad y competencias en educación para la sostenibilidad en la educación superior. *Uni-Pluriversidad* **2014**, *14*, 46–58.
88. Simon, R.; Farkas, G. Sex, class, and physical science educational attainment: Portions due to achievement versus recruitment. *J. Women Minor. Sci. Eng.* **2008**, *14*, 30–46. [CrossRef]
89. UNESCO. *Education for Sustainable Development Goals: Learning Objectives*; UNESCO: Paris, France, 2017.
90. Kolstø, S.D. Scientific Literacy for Citizenship: Tools for dealing with the science dimensión of controversial socio-scientific issues. *Sci. Educ.* **2001**, *85*, 291–310. [CrossRef]
91. Sterling, S. Higher Education, Sustainability, and the Role of Systemic Learning. In *Higher Education and the Challenge of Sustainability: Problematics, Promise, and Practice*; Corcoran, P.B., Wals, A.E.J., Eds.; Kluwer Academic Publishers: Dordrecht, The Netherland, 2004; pp. 47–70.
92. Zamora-Polo, F.; Sánchez-Martín, J.; Corrales-Serrano, M.; Espejo-Antúnez, L. What do university students know about sustainable development goals? A realistic approach to the reception of this UN program amongst the youth population. *Sustainability* **2019**, *11*, 3533. [CrossRef]
93. Gallego-Gil, D.; Nevot-Luna, A. Los estilos de aprendizaje y la enseñanza de las matemáticas. *Rev. Complut. Educ.* **2008**, *19*, 95–112.
94. Martínez-Geijo, P. Estilos de aprendizaje: Pautas metodológicas para trabajar en el aula. *Rev. Complut. Educ.* **2008**, *19*, 77–94.
95. Carter, L. Globalisation and science education: The implications of science in the new economy. *J. Res. Sci. Teach.* **2008**, *45*, 617–633. [CrossRef]
96. Hernández-Suárez, C.A.; Pabón-Galán, C.A.; Prada-Núñez, R. Desarrollo de competencias y su relación con el contexto educativo entre docentes de ciencias naturales. *Rev. Virtual Univ. Católica Norte* **2017**, *51*, 194–215.