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# An Experimental Study on the Implementation of a STEAM-Based Learning Module in Science Education

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**Abstract:** Over the last decade, there has been notable academic interest in the multidisciplinary studies of science education with the emergence of STEAM. Accordingly, this study aimed to conduct an experimental study to explore the effectiveness of a STEAM-based space-themed learning module in science education taught to primary school students. The sample of the study was 6th- and 7th-grade students from the Central Anatolia Region of Turkiye. The experimental group consisted of 180 students, whereas the control group consisted of 94 students. The STEAM-based learning module was applied to the students in the experimental group, and the traditional lecture-based approach was applied to students in the control group. The traditional education and intervention lasted eight weeks. The chi-square test and one-way ANOVA were used to analyze the differences and associations between the variables. The results indicated that gender and academic achievement level were the two key factors determining the effectiveness of the STEAM-based learning module. The comparison of the pre-test and post-test scores indicated that the scores of the female students who participated in the module increased the most. This suggested that girls benefited more from the STEAM-based learning module than boys. Further, the lecture-based approach led to a decrease in some high-achieving students. The findings have implications for educational policymakers, curriculum developers, and syllabus designers.

**Keywords:** STEAM; informal learning; science education; transversal competencies



**Citation:** Arpaci, I.; Dogru, M.S.; Kanj, H.; Ali, N.; Bahari, M. An Experimental Study on the Implementation of a STEAM-Based Learning Module in Science Education. *Sustainability* **2023**, *15*, 6807. https://doi.org/10.3390/su15086807

Academic Editor: Pedro Guilherme Rocha dos Reis

Received: 1 December 2022
Revised: 23 March 2023
Accepted: 12 April 2023
Published: 18 April 2023



## 1. Introduction

For centuries, human beings have wondered about stars and whether different planets exist elsewhere in the universe other than our world. Over the past few decades, several studies were carried out on this subject, and several theories have been put forward explaining the possibility of the existence of such planets [1]. Thanks to technological advancements over the past few decades, human beings have made significant progress in this field. Current trends in this field are topics such as touristic space travel and exploring new habitats in space [2,3]. This study, accordingly, dwelled on the students' views on space exploration. Touristic space travel and researching new space habitats are hot topics in this field. Therefore, the topic of space exploration was chosen for this study.

The terms STEM, STEAM, or STEMA have come into prominence in recent years because of their integrative solutions for traditional education problems [4]. STEM is "an educational approach that aims to identify problems with an interdisciplinary approach for students from pre-school to higher education by combining science, technology, engineering, and mathematics, and produce appropriate solutions to these problems" [5]. STEM highlights a form of research and inquiry-based learning by revealing the sense of curiosity

available to individuals [6]. After the advent of STEM education practices, it was thought that focusing on only four disciplines was not enough to fully meet the needs of students, and additions were made to expand the scope of STEM education [7–9]. Thus, the concept of "STEAM" emerged by adding "arts" to STEM disciplines [10].

STEAM is an acronym that combines the original STEM term with art, allowing educators to broaden the benefits of hands-on learning and cooperation in a variety of ways while still stimulating creativity and curiosity. The distinction between STEM and STEAM is in their approaches to scientific concepts. The STEM approach emphasizes using rigorous scientific, technological, mathematical, or engineering skills to advance or create new ideas, whereas the STEAM approach to learning guides student conversation, inquiry, and critical thinking through the use of "Science, Technology, Engineering, Arts, and Mathematics" as access points [11–13]. STEAM allows the inclusion of art-based and creative curriculum elements to enhance learning and bring real life into the classroom. This may include writing and telling stories, poetry, role-playing, and the use of design in addition to solutions, values/ethical discussions, etc. The biggest difference between STEAM and STEM is that STEAM lays out the basic aspects of the technology to create models and prototypes before building/deconstructing (engineering). All of these concepts are defined in John Dewey's 20th-century philosophy of education [14]. Bringing arts and mathematics into a more practical form by combining them facilitates the learning of students, especially those with low academic achievement [15,16]. One of the objectives of STEAM education is to motivate students about science, scientific developments, and scientific technologies by encouraging them to be self-starters and self-sustainers. In the STEAM framework, subjects are taught with an interdisciplinary approach to develop students' creativity and problem-solving skills [17–19]. To achieve this goal, STEAM contributes to teaching STEM disciplines, and arts in an interdisciplinary way, to students' understanding of scientific developments, and to improving their scientific literacy levels [20,21]. The most important concept in this approach is to relate course subjects to real-world examples. In this manner, science, technology, engineering, mathematics, and arts should be integrated into daily life as much as possible. The more relevant the subjects and problems students face related to the world around them in the course, the more likely they are to be motivated [22]. STEAM education is student-centered and inquiry-based and covers concepts such as project preparation, design, and innovation-oriented studies.

STEAM education contributes to the problem-solving skills and development of creative thinking skills of students [23]. Some studies involving middle school students [21] found that the mathematics-oriented STEAM education applied to students improved their interest in math class and had a negative-attitude-reducing effect. According to other studies [17,18], pupils' academic achievements in science classes have improved as a result of STEAM exercises implemented in middle school classes. The STEAM approach is not only beneficial for the development of students but also for teachers.

In this study, a learning module refers to an organized collection of learning activities designed to help students to comprehend the learning objectives systematically. Activities in the STEAM-based space-themed learning module were developed by the researchers based on the education curriculum defined by the Ministry of National Education. The purpose of the study was to explore the effectiveness of a STEAM-based space-themed learning module in science education taught to primary school students. Specifically, the following research questions were investigated in this study:

(1) Are the post-test scores of students who participated in the STEAM-based space-themed learning module different from those of students who did not participate in the module?
(2) Does the effectiveness of the module differ by gender?
(3) Does the effectiveness of the module have any correlation with the level of academic success?

## 2. Materials and Methods

### *2.1. Sample*

The sample of the study consisted of 274 secondary school students who continued their education in the 6th and 7th grades in the Central Anatolia Region in Turkiye (see Table 1). The study's experimental group was formed with 180 students. The control group consisted of 94 students. Participants were randomly selected among 544 students who volunteered to participate in the study. In this research, the student's cognitive structure and conceptual change model about design thinking were also evaluated. The design-oriented thinking process discussed within the scope of the research was evaluated following the processes described by Hasso Plattner [24].

**Table 1.** Distribution of participants by age range and gender.

| Age Group | Gender | Participant |
|---|---|---|
| 10–12 | Girls | 132 |
| | Boys | 142 |
| | Total | 274 |

### *2.2. Ethical Considerations*

Permission was obtained from the Ethics Committee of the University before conducting the study. Written consent forms were obtained from the families. All students were informed about the purpose of the study and confidentiality of the data was ensured. They were also assured of their right to terminate participation at any time.

### *2.3. STEAM-Based Learning Module*

While developing the module, we aimed to provide students with 21st-century skills. In the module, museum visits, environmental awareness activities, science exhibitions, and workshops were organized for the participant students. Afterward, a virtual space visit was arranged for the students with the help of information technology to uncover the solar system's mysteries. Furthermore, it was aimed to develop the cooperation and creativity skills of the students with creative tasks to be carried out with group work. Moreover, the evaluation activities related to the topic covered in the module helped in brainstorming with the students and discussing these topics. These activities allowed students to learn from each other and enhance their thinking strategies.

STEAM allows for arts-based and creative curriculum aspects to be included to enhance learning and bring real life into the classroom. This may include story writing and telling, poetry, role plays, using the design-based aspects of technology to create models and prototypes before building/making (engineering) solutions, values/ethical discussions, etc. Accordingly, the proposed learning module aimed to contribute to the success of students in following engineering design processes to create a system, design a product or put forward an alternative solution in STEAM-based education. In addition, it is believed that this module can contribute to the development of students' conceptual understanding of STEAM applications and their skills such as scientific creativity, cooperation, and the application of science and engineering together to solve a problem.

### *2.4. Evaluation*

In the present study, the participants were categorized into two groups: the control group and the experimental group. The STEAM-based space-themed learning module was applied to the students in the experimental group, and the traditional lecture-based approach was applied to students in the control group. The curriculum contents are the same in the related classes where the research is conducted. A pre-test was provided to students of both groups at the beginning of the module to determine their initial grasp of the learning, and a post-test was given shortly after the completion of the module to

determine what the students have learned. Körner et al. [23] developed tests for both pre- and post-intervention evaluation. These tests were created with multiple-choice questions that measured knowledge, reasoning, and application skills. Each multiple-choice question had four possible answers including a distractor.

All students were informed that these test results would not affect their course grades and were allowed to ask questions before signing consent forms. The questions presented to students in the tests were generally aimed at measuring outcomes related to science. The test questions were prepared based on the steps in Bloom's taxonomy of learning objectives, such as knowledge-based questions, comprehension questions, and conceptual questions (i.e., analysis, synthesis, and evaluation). Visuality was at the forefront of some questions, and students were expected to answer these questions based on their prior knowledge. In addition, the test included questions about visuality and logical reasoning.

## 3. Results

Students were asked 27 questions in both the pre-test and post-test. The Cronbach alpha coefficient of the pre-test was 0.78, and the Cronbach alpha coefficient of the post-test was 0.75. Within the scope of this study, students were grouped into the lower 25% group, the 50% group, and the top 25% group according to their academic achievement levels. In the group below 25% in terms of academic performance, the final test scores of the students who participated in the STEAM-based space learning module and the students who did not participate improved. On the other hand, the students who participated in the module, who were in the top 25% group in terms of academic performance, showed more improvement compared to those who did not participate. Moreover, there was a decrease in the post-test scores of the students who did not participate in the module in the top 25% groups. In all groups, students who participated in the module had higher scores on the post-test than pre-test. In addition, gender and participation in the STEAM-based space-themed learning module were other grouping criteria. Both boys and girls who participated in the module showed significant improvements at the end of the intervention.

One-way variance analysis (ANOVA) was used to determine how much learning occurred before and after the intervention and to determine the degree to which post-test scores were related to students' academic achievement level and gender [25]. Test scores of students who participated in the module and did not participate reveal that both groups improved their scores significantly. Examining whether students participated in the module also revealed statistically significant relationships between pre-and post-test scores and gender. In addition, a statistically significant relationship was found between pre-test and post-test scores based on whether students participated in the module and their gender. Table 2 shows the pre-test and post-test results based on the student's participation in the module and their gender.

**Table 2.** Pre-test and post-test results by gender.

| Participation | Gender | | Mean | S.D. | Std. Error | N |
|---|---|---|---|---|---|---|
| Yes | Girls | Pre-test | 33.99 | 5.84 | 0.26 | 110 |
| | | Post-test | 36.95 | 4.20 | 0.20 | 110 |
| | Boys | Pre-test | 33.10 | 6.12 | 0.28 | 92 |
| | | Post-test | 36.08 | 4.26 | 0.21 | 92 |
| No | Girls | Pre-Test | 33.24 | 5.89 | 0.28 | 70 |
| | | Post-Test | 35.10 | 5.01 | 0.25 | 70 |
| | Boys | Pre-test | 32.44 | 6.87 | 0.21 | 40 |
| | | Post-test | 35.64 | 5.38 | 0.19 | 40 |

Girls who did not participate in the STEAM-based space-themed learning module barely improved their post-test scores. Male students who did not participate in the module had lower pre-test scores than other groups. The standard deviation of the pre-test score

for this group was higher than the post-test score, indicating that students with the lowest pre-test scores managed to reduce the difference between students who performed better in the post-test than in the pre-test. It was found that there was little difference between the levels of development shown by the boys and girls who participated in the module.

Students are divided into those with lower scores or the same (0 or Neg) and higher scores (Pos) in these two groups. The results indicated that most of the students (n = 168) improved their scores. It was found that 111 students improved their post-test scores and 25 students' pre-and post-test scores remained the same. In addition, the results were examined for both students who participated in the STEAM-based space-themed learning module and did not participate. Table 3 shows a comparison of the student's test scores by gender before and after the intervention.

**Table 3.** Comparison of the student's test scores.

| Gender | | | | Participation | | Total |
|---|---|---|---|---|---|---|
| | | | | Yes | No | |
| Boys | Neg-or-0/Pos | 0 or Neg | Count | 24 | 18 | 42 |
| | | | EC | 22.5 | 19.5 | 42 |
| | | | AR | 0.7 | −0.7 | |
| | | Pos | Count | 63 | 27 | 90 |
| | | | EC | 64.5 | 25.5 | 90 |
| | | | AR | −0.5 | 0.5 | |
| | Total | | Count | 92 | 38 | 132 |
| | | | EC | 92 | 38 | 132 |
| Girls | Neg-or-0/Pos | 0 or Neg | Count | 54 | 48 | 102 |
| | | | EC | 60.2 | 42.5 | 102 |
| | | | AR | −3.1 | 3.1 | |
| | | Pos | Count | 34 | 44 | 78 |
| | | | EC | 27.1 | 50.9 | 78 |
| | | | AR | 3.1 | −3.1 | |
| | Total | | Count | 110 | 70 | 180 |
| | | | EC | 110 | 70 | 180 |
| Total | Neg-or-0/Pos | 0 or Neg | Count | 78 | 66 | 144 |
| | | | EC | 82.7 | 62 | 144.7 |
| | | | AR | −2.4 | 2.4 | |
| | | Pos | Count | 97 | 71 | 168 |
| | | | EC | 91.6 | 76.4 | 168 |
| | | | AR | 2.6 | −2.6 | |
| | Total | | Count | 202 | 108 | 312 |
| | | | EC | 202 | 108 | 312 |

EC: Expected Count, AR: Adjusted Residual.

There was a difference between the expected scores and the obtained scores only for female students, with the expected post-test score for female students participating in the module being 7.1, while the obtained score as a result of the test was 34. When the results were examined for male students, it was found that there was not much difference between the expected scores and the obtained scores. When examined for the negativity or positivity

of the pre-test and post-test scores, it seems that the female students benefited more from the module. The statistical importance of these results was shown in Table 4.

**Table 4.** Chi-square analysis results for the female students.

| | Gender | Value | DF | Asymptotic Significance (Two-Sided) | Exact Sig. (Two-Sided) | Exact Sig. (One-Sided) |
|---|---|---|---|---|---|---|
| Girls | Chi-Square | 5.81 | 1 | 0.048 | | |
| | Likelihood Ratio | 5.67 | 1 | 0.049 | | |
| | Fisher's Exact Test | | | | 0.53 | 0.40 |
| | Continuity Correction | 4.02 | 1 | 0.067 | | |
| | Linear-by-Linear Association | 5.67 | 1 | 0.49 | | |
| | N of Valid Cases | 180 | | | | |

The chi-square value for female students was found to be 5.81, and the *p*-value was found to be 0.048. Thereby, it can be assumed that the STEAM-based space-themed learning module was more effective for female students. As a result of the ANOVA analysis, there was no significant differentiation in the pre- and post-test scores of the boys and girls who participated in the module. In addition, when the values of the pre-and post-test scores were examined, it was concluded that the female students who participated in the module had a higher post-test score than the male students. After evaluating the effectiveness of the module by gender, the same analysis was carried out based on the academic achievement levels of the students. Table 5 shows a comparison of test scores according to the student's GPA before and after the intervention.

**Table 5.** Comparison of the test scores.

| Percentile Group of GPA | | | | Participation | | Total |
|---|---|---|---|---|---|---|
| | | | | Yes | No | |
| 1 | Neg-or-0/Pos | 0 or Neg | Count | 26 | 12 | 38 |
| | | | EC | 26.2 | 11.8 | 38 |
| | | | AR | −0.1 | 0.1 | |
| | | Pos | Count | 36 | 16 | 52 |
| | | | EC | 35.8 | 16.2 | 52 |
| | | | AR | 0.1 | −0.1 | |
| | | Total | Count | 62 | 28 | 90 |
| | | | EC | 62.0 | 28.0 | 90 |
| 2 | Neg-or-0/Pos | 0 or Neg | Count | 54 | 15 | 69 |
| | | | EC | 54.7 | 14.3 | 69 |
| | | | AR | −0.3 | 0.3 | |
| | | Pos | Count | 88 | 22 | 110 |
| | | | EC | 87.3 | 22.7 | 110 |
| | | | AR | 0.3 | −0.3 | |
| | | Total | Count | 142 | 37 | 179 |
| | | | EC | 142 | 37 | 179 |

**Table 5.** *Cont.*

| Percentile Group of GPA | | | | Participation | | Total |
|---|---|---|---|---|---|---|
| | | | | Yes | No | |
| 3 | Neg-or-0/Pos | 0 or Neg | Count | 17 | 12 | 29 |
| | | | EC | 21.3 | 7.7 | 29 |
| | | | AR | −2.2 | 2.2 | |
| | | Pos | Count | 52 | 13 | 65 |
| | | | EC | 47.7 | 17.3 | 65 |
| | | | AR | 2.2 | −2.2 | |
| | | Total | Count | 69 | 25 | 94 |
| | | | EC | 69 | 25 | 94 |

EC: Expected Count, AR: Adjusted Residual 1: Top 25% group by GPA 2: Group of 50% according to GPA 3: Top 25% group by GPA.

Table 5 shows that the test scores after the intervention in the 1st and 2nd groups did not differ significantly from the expected score. Furthermore, it was found that the most benefited group from the module was the group with high academic success (the third one, which participated in the module). The expected post-test score of the group students was 47.7. The post-test score obtained after the intervention was 52. In addition, if the students did not participate in the module, their post-test scores decreased. Data from the first two groups and the sum of all groups were not considered at this stage of the analysis because they did not reveal statistically significant findings. Table 6 shows the chi-square analysis results for the third-group students' scores.

**Table 6.** Chi-square analysis results for the third-group students' scores.

| | Gender | Value | DF | Asymptotic Significance (Two-Sided) | Exact Sig. (Two-Sided) | Exact Sig. (One-Sided) |
|---|---|---|---|---|---|---|
| Girls | Chi-Square | 5.19 | 1 | 0.038 | | |
| | Likelihood Ratio | 5.67 | 1 | 0.055 | | |
| | Fisher's Exact Test | | | | 0.049 | 0.40 |
| | Continuity Correction | 4.12 | 1 | 0.064 | | |
| | Linear-by-Linear Association | 6.12 | 1 | 0.059 | | |
| | N of Valid Cases | 127 | | | | |

The chi-squared value for the third group was 5.19, and the *p*-value was 0.038. Accordingly, it can be argued that the module is more useful for students with higher academic achievement levels. Note that students' pre-test scores should be similar and students who had not improved their post-test scores should be considered. Multivariate variance analysis (MANOVA) was employed to reveal such situations. The results obtained from this analysis are introduced in Table 7.

Table 7 indicated that students who scored lower on the post-test had slightly better scores on the pre-test (pre-test and post-test score difference; 2.39 points). In addition, in the post-test, students who increased their post-test (Pos) scores also passed the scores of students in the Neg-or-0 groups, while the average score of students in the Neg-or-0 group was close to the pre-test score of students in the Pos group. When the pre-test and post-test scores were evaluated separately, it was concluded that students who scored relatively low on the pre-test were more likely to achieve higher scores on the post-test, and students who scored higher on the pre-test were more likely to achieve lower scores on the post-test.

When examining the scores of the students from both tests, it was found that the gender and whether the students improved their scores had no significant impact on the

pre-test and post-test scores. However, when these factors were evaluated together, it was found to affect both pre-test and post-test scores. Standard deviations (S.D.) and averages (Mean) are shown in Table 8.

**Table 7.** Standard deviations and mean scores of the pre-test and post-test scores.

| | Neg-or-0 Pos | Mean | S.D. | Std. Error | N |
|---|---|---|---|---|---|
| Pre-test | 0 or Neg | 37.31 | 11.21 | 0.27 | 132 |
| | Pos | 34.92 | 12.57 | 0.22 | 168 |
| | Total | 35.37 | 11.79 | 0.24 | 330 |
| Post-test | 0 or Neg | 34.53 | 12.86 | 0.23 | 168 |
| | Pos | 39.27 | 10.46 | 0.28 | 141 |
| | Total | 37.61 | 11.38 | 0.21 | 330 |

**Table 8.** The standard deviation of scores by students' scores after the intervention.

| | Neg-or-0 Pos | Gender | Mean | S.D. | Std. Error | N |
|---|---|---|---|---|---|---|
| Pre-test | 0 or Neg | Girl | 32.41 | 5.94 | 0.22 | 102 |
| | | Boy | 33.74 | 5.27 | 0.19 | 30 |
| | | Total | 33.14 | 5.62 | 0.12 | 132 |
| | Pos | Girl | 33.10 | 4.31 | 0.29 | 78 |
| | | Boy | 32.52 | 4.62 | 0.07 | 90 |
| | | Total | 32.31 | 4.50 | 0.27 | 168 |
| | Total | Girl | 37.49 | 4.70 | 0.22 | 168 |
| | | Boy | 35.47 | 5.20 | 0.29 | 132 |
| | | Total | 36.48 | 5.03 | 0.09 | 300 |
| Post-test | 0 or Neg | Girl | 29.50 | 6.12 | 0.16 | 102 |
| | | Boy | 30.82 | 5.62 | 0.21 | 30 |
| | | Total | 30.41 | 5.85 | 0.20 | 132 |
| | Pos | Girl | 38.16 | 4.11 | 0.29 | 78 |
| | | Boy | 37.41 | 4.28 | 0.19 | 90 |
| | | Total | 37.84 | 4.21 | 0.21 | 168 |
| | Total | Girl | 38.93 | 5.57 | 0.26 | 168 |
| | | Boy | 37.69 | 6.00 | 0.25 | 132 |
| | | Total | 38.31 | 5.75 | 0.26 | 300 |

Based on Table 8, it can be argued that gender has a share in students' pre-test and post-test scores. Further, according to the GPA, the difference between the student's pre-test and the post-test score was negative or positive, but it did not have a statistically significant effect on the pre-test or post-test scores. By evaluating the impacts of both variables on test scores individually, it was determined whether the academic achievement level affected the pre-test and post-test scores.

Table 9 indicates the mean scores and standard deviations of the pre-test and post-test for the six factors mentioned above. The difference between the scores of the top 25% and the 75% group was more pronounced than the students in the group who lowered or failed to improve their scores on the last test. There was almost no difference between the pre-test and post-test scores of the students in these groups.

In this study, students' participation in the STEAM-based space-themed learning module can be an important factor in their test scores. For this reason, students were once again divided into two groups based on whether they increased their post-test scores or not. The positivity of the difference between the pre-test and post-test scores was statistically significant for both pre-test and post-test scores for the students who participated and did not participate in the module. In students who did not participate in the module, a negative or positive differentiation of the post-test and pre-test scores made the pre-test

score more effective. In addition, the post-test scores of the students participating in the module were more predictable. In Table 10, standard deviations of post-test and pre-test scores of module and control groups are given. Although students who did not participate in the module had wider score intervals in their pre-test results, it was observed that the given interval tends to decrease after the post-test. In contrast, students who participated in the module had closer pre-test scores and wider score intervals on their post-test results.

**Table 9.** The standard deviation of the student's scores.

| | Neg-or-0 Pos | Percentile Group of GPA | Mean | S.D. | Std. Error | N |
|---|---|---|---|---|---|---|
| Pre-test | 0 or Neg | 1 | 28.39 | 6.21 | 0.25 | 40 |
| | | 2 | 35.34 | 4.13 | 0.21 | 69 |
| | | 3 | 36.63 | 4.02 | 0.29 | 41 |
| | | Total | 33.53 | 4.36 | 0.13 | 150 |
| | Pos | 1 | 29.89 | 4.09 | 0.19 | 68 |
| | | 2 | 31.33 | 4.73 | 0.22 | 130 |
| | | 3 | 32.44 | 4.22 | 0.27 | 87 |
| | | Total | 31.64 | 4.33 | 0.20 | 285 |
| | Total | 1 | 29.14 | 4.85 | 0.12 | 141 |
| | | 2 | 33.34 | 5.93 | 0.18 | 191 |
| | | 3 | 34.53 | 4.24 | 0.23 | 127 |
| | | Total | 32.63 | 5.04 | 0.21 | 459 |
| Post-test | 0 or Neg | 1 | 28.16 | 6.28 | 0.29 | 40 |
| | | 2 | 31.53 | 4.62 | 0.17 | 69 |
| | | 3 | 35.12 | 5.85 | 0.21 | 41 |
| | | Total | 31.27 | 5.87 | 0.25 | 150 |
| | Pos | 1 | 34.92 | 4.14 | 0.23 | 68 |
| | | 2 | 37.34 | 4.55 | 0.26 | 130 |
| | | 3 | 39.18 | 3.78 | 0.21 | 87 |
| | | Total | 36.66 | 4.53 | 0.18 | 285 |
| | Total | 1 | 29.61 | 5.91 | 0.18 | 141 |
| | | 2 | 33.43 | 5.48 | 0.23 | 191 |
| | | 3 | 34.48 | 4.71 | 0.05 | 127 |
| | | Total | 33.31 | 5.33 | 0.22 | 459 |

**Table 10.** Standard deviations of the student's pre-test and post-test scores.

| Participate in Module | Neg-or-0 Pos | Mean | S.D. | Std. Error | N |
|---|---|---|---|---|---|
| Pre-test Yes | 0 or Neg | 33.21 | 0.22 | 0.22 | 92 |
| | Pos | 30.70 | 0.24 | 0.24 | 97 |
| | Total | 31.53 | 0.27 | 0.27 | 189 |
| Post-test | 0 or Neg | 30.18 | 0.11 | 0.11 | 92 |
| | Pos | 34.11 | 0.14 | 0.14 | 97 |
| | Total | 32.15 | 0.26 | 0.26 | 189 |
| | 0 or Neg | 34.07 | 0.24 | 0.24 | 40 |

**Table 10.** *Cont.*

| Participate in Module | Neg-or-0 Pos | Mean | S.D. | Std. Error | N |
|---|---|---|---|---|---|
| Pre-test | Pos | 28.92 | 0.21 | 0.21 | 71 |
| No | Total | 32.53 | 0.26 | 0.26 | 111 |
| | 0 or Neg | 30.13 | 0.29 | 0.29 | 40 |
| Post-test | Pos | 33.50 | 0.22 | 0.22 | 71 |
| | Total | 32.31 | 0.23 | 0.23 | 111 |

## 4. Discussion and Conclusions

In Turkiye, the evaluation of students is carried out with scores in the range of 0 to 100 points. The average GPA of all the students who participated in the study was 73.9 with a standard deviation of 0.73. Accordingly, it can be said that the students who participated in the study usually have a reasonable level of academic achievement. When the post-test scores of the control and experimental groups were examined, it was found that the achievement of the students in both groups increased. In addition, it has been determined that there are more remarkable improvements in the students who participated in the STEAM-based space-themed learning module. This indicated that the proposed module was as effective as traditional classroom education.

The results indicated that in the lower 25% groups in terms of academic performance, the students who participated or did not in the STEAM-based space-themed learning module improved their post-test scores. On the other hand, in the top 25% groups in terms of academic performance, the students who participated in the module showed better improvement than those who did not participate. Moreover, there was a decrease in the post-test scores of the students who did not participate in the module in the top 25% groups. In all groups, students who participated in the module had higher scores on the post-test than pre-test. However, the proposed module was more useful for students with higher academic achievement levels. Among the students who participated in the module, the top 25% groups in terms of academic achievement level had the most improved scores. This finding differs from the findings of Chen et al. [26] and Ozkan et al. [20], while it is similar to the findings of Piila et al. [16].

When the post-test scores of the control group were examined, it was recognized that the post-test scores of the top 25% of students decreased, whereas the lower 25% group in terms of academic achievement improved their post-test scores. This can be explained by the ceiling effect. The ceiling effect is a scale attenuation effect, observed when an argument no longer affects a dependent variable or when the level above the variance in an argument is no longer measured [27]. Students who already have a high level of academic achievement probably did not make much progress because they were already good at it.

The results indicated that both boys and girls who participated in the STEAM-based space-themed learning module showed significant improvements as a result of participation in the module. The girls who did not participate in the module slightly increased their scores, while boys who did not participate in the module highly improved their scores. Test scores of the female students who participated in the module increased the most.

Family and other environmental factors may influence the development of gender roles from childhood [28]. For example, situations such as future attitudes and professional choices appear permanently in youth [29]. Out-of-school learning and informal learning have been discovered to reduce the gender gap and support non-traditional career options with the help of extracurricular activities and teacher encouragement [29]. Accordingly, this study also took possible gender differences into account, since female students and women are underrepresented in many fields related to science [30–32]. The girls appear to have benefited more from the proposed module. When examining the learning status in this study, their improvement is remarkable, especially given the gender gap, and so is the magnitude of this learning. This can be explained by many factors. The fact is that the girls

were relatively more successful in the pre-test than the boys. This may have affected the emergence of this condition. This finding is similar to the findings of Piila et al. [16].

In conclusion, the study investigated the effectiveness of the STEAM-based space-themed learning module for primary school students. Accordingly, the STEAM-based learning module was developed and applied to randomly selected experimental and control groups for eight weeks. A comparison of the post-test and pre-test scores revealed that girls benefited more from the module than boys. Girls may have benefitted more since there was more social interaction and collaborative learning in the STEAM module. All students who participated in the STEAM-based learning module increased their scores, but the proposed module was more useful for students with higher academic achievement levels. The results implied that out-of-school learning activities may reduce gender differences both in terms of cognitive learning and motivation. These findings have implications for educational policymakers, curriculum developers, and syllabus designers.

The study has certain limitations. Some schools that participated in the experimental study were specialized schools in the field of science, and their students' academic achievement profiles differ. Therefore, repeating this study with larger and more homogeneously distributed samples may also be useful. Another limitation of the study was that the control group students could not make up for a missed learning opportunity. Future studies can investigate the effectiveness of the STEAM-based learning module in other geographical locations to enhance the generalizability of the findings. Future studies are recommended to investigate the role of personality-related factors such as self-efficacy, innovativeness, and self-esteem on the effectiveness of the proposed learning module. Finally, recent research revealed that using novel approaches that combine classical structural equation modeling with AI-based algorithms can provide more robust results by considering both linear and non-linear relationships [24]. Future studies are recommended to develop a predictive model to identify factors determining the educational sustainability of the proposed learning module.

**Author Contributions:** Conceptualization, M.S.D. and I.A.; methodology, I.A.; software, H.K.; validation, N.A., M.B. and H.K.; formal analysis, M.S.D.; investigation, I.A.; resources, M.S.D.; data curation, N.A.; writing—original draft preparation, M.S.D.; writing—review and editing, I.A.; visualization, H.K.; supervision, M.B.; project administration, M.B.; funding acquisition, H.K. and N.A. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research received no external funding.

**Institutional Review Board Statement:** The study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Review Board (or Ethics Committee) of Kastamonu University (25 December 2020/66/4).

**Informed Consent Statement:** Informed consent was obtained from all subjects involved in the study.

**Data Availability Statement:** Data will be available upon request.

**Conflicts of Interest:** The authors declare no conflict of interest.

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