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ARAŞTIRMA MAKALESİ / RESEARCH ARTICLE

The Impact of STEM Education on Disadvantaged Elementary Students: Science Attitudes and Collaborative Learning Skills*

STEM Eğitiminin Dezavantajlı İlkokul Öğrencileri Üzerindeki Etkisi: Fen Tutumu ve İşbirlikli Öğrenme Becerileri

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Abstract

This study aims to examine the impact of a STEM education intervention designed for disadvantaged students on their attitudes toward science and their collaboration skills. The disadvantaged group addressed in the study consists of students who are socioeconomically disadvantaged and those under temporary protection. In this study, the pre-test–post-test control group quasi-experimental design one of the experimental research methods, was adopted. Within the scope of the research, a STEM education intervention was implemented for 4th-grade students in the units "Properties of Matter" and "Lighting and Sound Technologies." The research was conducted at a primary school located in a province in the Southeastern Anatolia Region of Türkiye, where approximately 80% of the student population is composed of disadvantaged students. A total of 46 fourth-grade students participated in

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the study, with 24 in the experimental group and 22 in the control group. According to the results of this study, the STEM activities implemented in science education significantly improved the attitudes of students from disadvantaged groups toward science and enhanced their collaborative learning skills. These results highlight the need to more widely adopt STEM-based approaches as an effective pedagogical tool in science education for disadvantaged student populations.

Keywords: STEM, collaborative learning skills, science attitudes, disadvantaged students, elementary students

Öz

Bu *çalışma* dezavantajlı *öğrencilere* yönelik bir STEM eğitimi uygulamasının, *öğrencilerin* fen bilimlerine yönelik tutumları ile işbirliği becerilerine olan etkisini incelemeyi amaçlamaktadır. Araştırma kapsamında ele alınan dezavantajlı grubu; sosyo-ekonomik açıdan dezavantajlı olan *öğrenciler* ile geçici koruma altındaki *öğrenciler* oluşturmaktadır. Çalışmada, deneysel araştırma türlerinden *ön* test–son test kontrol gruplu yarı deneysel desen benimsenmiştir. Araştırma kapsamında, 4. sınıf *öğrencilerine* "Maddenin *Özellikleri*" ve "Aydınlatma ve Ses Teknolojileri" *ünitelerinde* STEM eğitimi müdahalesi uygulanmıştır. Araştırma, Türkiye'nin Güneydoğu Anadolu Bölgesi'nde yer alan bir ilde, yaklaşık %80'ini dezavantajlı *öğrencilerin*oluşturduğu bir ilkokulda 4. sınıf düzeyinde gerçekleştirilmiştir. Deney grubunda 24, kontrol grubunda 22 olmak *üzere* toplam 46 *öğrenci* araştırmaya dâhil edilmiştir. Bu *çalışmanın* bulgularına göre fen eğitiminde uygulanan STEM etkinlikleri, dezavantajlı gruplardan gelen *öğrencilerin* fen bilimlerine yönelik tutumlarını ve işbirlikli *öğrenme* becerilerini anlamlı düzeyde geliştirmiştir. Bu sonuçlar, dezavantajlı *öğrenci* grupları için fen eğitiminde STEM temelli yaklaşımların etkili bir pedagojik araç olarak yaygınlaştırılmasını *önermektedir*.

Anahtar Kelimeler: STEM, işbirlikli *öğrenme* becerileri, fen tutumları, dezavantajlı *öğrenci*ler, ilkokul *öğrencileri*

INTRODUCTION

The widening gap between the increasing demand for a science, technology, engineering, and mathematics education (STEM) workforce and the declining number of students pursuing STEM fields has made it more critical than ever to cultivate positive attitudes toward science among learners (Summers & Abd-El-Khalick, 2018). Indeed, fostering positive attitudes toward science is widely recognized as one of the fundamental goals of contemporary science education (Wan & Lee, 2017). Moreover, modern educational perspectives go beyond merely transmitting knowledge; they emphasize equipping individuals with 21st-century skills such as applying knowledge to real-life problems, thinking critically, communicating effectively, and producing creative solutions (Murnawianto & Rahardjo, 2019). In the context of science education, nurturing individuals with these competencies has become one of the primary aims of learning environments. STEM education is considered one of the most effective approaches for developing such skills (Kuo et al., 2019). Among these skills, collaboration stands out as a critical component that supports both academic achievement and students' social development. Research shows that collaborative environments reduce student isolation, strengthen peer relationships, and make learning more inclusive (Leyva et al., 2021). In STEM activities, students are expected to collaboratively solve interdisciplinary problems much like in real life, positioning collaboration as a central element of STEM-based learning (Capraro & Jones, 2013).

Given these characteristics, STEM education offers important opportunities particularly for disadvantaged students who may require strong social support and effective communication environments. In classrooms where students from diverse cultural backgrounds such as those affected by migration come together, the need for inclusive instructional approaches is increasing. Although STEM education has become widespread globally, Musker (2024) notes that research on both formal and informal STEM learning experiences remains limited for disadvantaged and underrepresented groups. Another key emphasis in the literature concerns the long-term impact of introducing children to STEM at an early age. Scholars highlight that the STEM journey begins early and continues throughout life (Guelfi, 2022). The STEM education report published in Türkiye (MoNE, 2016) similarly aims to expand STEM practices from early childhood to higher education; however, existing research tends to concentrate largely on middle – and high-school levels (Herdem & Ünal, 2018). The limited number of studies conducted with elementary-school students and disadvantaged groups indicates a need for more empirical evidence regarding their STEM experiences. Addressing this gap, the present study examines the effects of a STEM education on elementary students' attitudes toward science and their collaborative learning skills, with a focus on disadvantaged populations.

Literature Review

STEM education is defined as an interdisciplinary learning approach that integrates the fields of science, technology, engineering, and mathematics (Marshall, 2015). Çorlu and colleagues (2014) describe STEM as a holistic process in which teachers and students collaboratively generate knowledge, skills, and ideas. Vasquez and his colleagues (2013) similarly define STEM as a multidisciplinary instructional approach that eliminates traditional disciplinary boundaries. In STEM real-life phenomena are connected with the core STEM disciplines to support the development of essential 21st-century skills. This interdisciplinary approach emphasizes not only conceptual knowledge and process skills but also the ability to cope with situations and solve problems (Murnawianto & Rahardjo, 2019). These definitions collectively demonstrate that STEM is not merely the combination of content areas; rather, it provides a framework centered on student engagement, problem solving, production, and collaboration-based learning.

STEM's multidimensional and interactive nature naturally foregrounds students' collaborative learning processes. Core elements of STEM activities, such as problem solving and design development, inherently require students to work together, negotiate ideas, and integrate individual contributions into shared outcomes (Elsey, 2019). In this context, cooperative learning is considered an effective instructional approach in which students work in heterogeneous small groups toward a common goal, engage in peer learning, and actively participate in the learning process while developing self-confidence, communication, and problem-solving skills (Doymuş et al., 2004). Due to these characteristics, cooperative learning aligns strongly with the nature of STEM activities (Durkin, 2018) and is widely used in STEM implementations (Elsey, 2019; Bakan & Bircan, 2025; Capraro & Jones, 2013). This context makes the potential importance of STEM even more visible in classrooms where students from diverse socioeconomic and cultural backgrounds learn together. In increasingly diverse classroom environments shaped especially by migration, challenges such as language barriers, social isolation, and adaptation problems are known to directly affect students' learning

processes (Rossi, 2009). Studies conducted in Türkiye indicate that students under temporary protection experience difficulties in adapting to school due to language and communication barriers (Başar et al., 2018), and that current instructional programs cannot fully address these needs (Özer et al., 2016). UNICEF (2016) broadly defines disadvantaged children as street children; children living in impoverished regions; migrant, refugee, and asylum-seeking children; children with health problems; and children married at an early age. Additionally, living in or coming from rural areas, experiencing language barriers, inadequate school conditions, and disruptions in educational processes due to war, terrorism, or natural disasters are among the factors contributing to disadvantage (Howie et al., 2008).

In recent years, the largest disadvantaged group in Türkiye has been Syrian students under temporary protection. As of 2024, more than 3 million Syrians reside in Türkiye (Directorate General of Migration Management, Ministry of Interior, 2024). While some of these students live in camps, others attend public schools alongside Turkish students. This situation leads to the direct reflection of socioeconomic inequalities, cultural adaptation challenges, and language barriers on the educational process. Research shows that low socioeconomic status negatively affects not only academic achievement but also attitudes toward science (Gorard & See, 2009; Hanushek, 2010; Fındık & Kavak, 2013). However, student-centered and hands-on approaches have been shown to mitigate these negative effects (Seçgin & Sungur, 2021). Indeed, the study conducted by Yalçın and colleagues (2022) revealed that STEM-based education increased Syrian students' interest in science education, enhanced their sense of curiosity, and supported their collaboration skills. These results indicate that learning environments designed for disadvantaged students must address both academic goals and social-emotional developmental needs. In line with the evidence underscoring the importance of designing supportive learning environments for disadvantaged students, prior research at the elementary level demonstrates that STEM education offers multifaceted benefits for students. For example, Yıldız and Ecevit (2022) found that paleontology-themed STEM activities enhanced students' learning motivation and teamwork skills; Karakaya and colleagues (2019) reported that STEM activities connected to real-life problems improved academic achievement, communication, and career awareness. Similarly, Bircan and Çalışıcı (2022) showed that STEM practices positively influence attitudes toward science, technology, engineering, and mathematics while significantly supporting 21st-century skills. These results indicate that STEM provides a powerful learning environment that enriches students' cognitive and affective development.

This study examines to impact of a STEM education implemented with disadvantaged elementary students on their attitudes toward science and their collaboration skills. The disadvantaged group in this research consists of socioeconomically disadvantaged students and students under temporary protection. In this context, the study evaluates a STEM experience that may contribute to fostering more positive attitudes toward science and strengthening collaborative learning skills among this student population.

Theoretical Framework

In this study, the interpretation of the results related to collaborative learning is informed by the cooperative learning framework proposed by Johnson, Johnson, and Holubec (1994), which identifies five essential components for successful collaborative learning. These components are: (1) Positive interdependence is established when students perceive that their individual success is linked to the

success of their peers, fostering a sense of shared goals and mutual responsibility. (2) Promotive interaction refers to students' active engagement with one another through discussion, explanation, and encouragement, which supports the co-construction of knowledge. (3) Individual accountability ensures that each group member is responsible for contributing to the group's work, thereby preventing unequal participation and social loafing. (4) Interpersonal and small-group social skills, such as communication, trust-building, leadership, and conflict management, are essential for effective collaboration and must be explicitly taught and practiced rather than assumed to develop naturally. (5) Group processing and reflecting involves students' collective reflection on their group functioning, including evaluating their collaborative processes and making decisions to improve future group work. Together, these components provide a comprehensive framework for understanding how cooperative learning can support both academic and social learning outcomes when implemented systematically.

Aim of the Study and Research Questions

This study aims to provide important insights into the integration of STEM education into the elementary level and its applicability among students with diverse socioeconomic and cultural backgrounds. The limited empirical evidence regarding the effects of early STEM experiences and STEM practices for disadvantaged groups makes this research valuable both pedagogically and in terms of designing inclusive and equity-oriented learning environments. The results obtained are expected to contribute to educational policies and instructional practices.

The study was guided by the following research questions:

1. What is the effect of STEM education on the science attitudes of disadvantaged elementary students?
2. What is the effect of STEM education on disadvantaged elementary students' collaborative learning skills and its sub-dimensions?

METHOD

Research Design

In this study, a quasi-experimental pretest-posttest control group design, which is one of the experimental research methods, was adopted (Creswell & Creswell, 2017). The study examined the effects of the intervention on students' attitudes toward science and their Collaborative learning skills in both experimental and control groups. While the experimental group received science instruction enriched with STEM activities, the control group continued with the standard curriculum without any intervention. Further details regarding the implementation process are provided under the relevant section.

Study Group

The research was conducted at a public elementary school located in a southeastern province of Türkiye, where approximately 80% of the student population is considered disadvantaged. The study group was determined through convenience sampling. The first author works as a 4th-grade teacher at the selected school. Among the five 4th-grade classrooms, the class taught by the researcher was

selected as the experimental group. The control group was chosen from among the remaining four classes based on similar academic achievement levels and student profiles. Accordingly, a total of 46 students participated in the study 24 in the experimental group and 22 in the control group.

The participants were between 9 and 10 years old. The experimental group consisted of 8 migrant and 16 Turkish students, while the control group included 9 migrant and 13 Turkish students. All migrant students were fluent in Turkish. The gender distribution was balanced in both groups: the experimental group included 12 girls and 12 boys, while the control group included 10 girls and 12 boys. All participants were classified as disadvantaged students. All students came from low socioeconomic backgrounds. Approximately 82.6% of the families had a minimum wage income, while the remaining families had even lower incomes. Most households were supported financially by the father, and only 4.6% of the mothers were employed in regular jobs. Although students under temporary protection status benefited from government support, they still faced various limitations in accessing education, housing, nutrition, and learning materials. The demographic characteristics of the study group are presented in Table 1.

Table 1.

The Demographic Characteristics of the Study Group

Variable	Experimental Group (n = 24)	Control Group (n = 22)	Total (n = 46)
Gender			
Girls	12	10	22
Boys	12	12	24
Migration Status			
Migrant	8	9	17
Non-migrant (Turkish)	16	13	29

Data Collection Instruments

Two instruments were used to collect data in this study. The "Science Attitude Scale (SAS)" suitable for 4th-grade students was used to measure students' attitudes toward science, and the "Collaborative Learning Skills Scale (CLSS)" was used to assess their Collaborative learning skills. Both instruments were administered after obtaining ethical approval, permission from the Directorate of National Education, and parental consent.

Science Attitude Scale (SAS)

Originally developed by Wang and Berlin (2010), the Science Attitude Scale was adapted into Turkish by Tosun and Genç (2015). The original version consists of a single factor and 30 items. The Turkish version was administered to 1,013 students attending public schools. To assess construct validity, exploratory and confirmatory factor analyses were conducted. Based on the results, the adapted scale was finalized with 26 items under a single factor. The Cronbach's alpha internal consistency coefficient for the entire scale was found to be .916, indicating high reliability (Tosun & Genç, 2015). The scale is a five-point Likert-type instrument, with items scored between 1 and 5. It includes 13 negatively worded items. The total possible score ranges from 26 to 130.

Collaborative Learning Skills Scale (CLSS)

Developed by Burak (2020) for elementary students, the Collaborative Learning Skills Scale (CLSS) was originally designed in alignment with the five core components of cooperative learning proposed by Johnson, Johnson, and Holubec (1994). However, following the statistical analyses conducted during the scale development process, some items were excluded due to insufficient psychometric properties. As a result, the final version of the scale yielded a three-factor structure that captures key dimensions of the cooperative learning process. The final scale consists of 17 items grouped under three factors: (1) Working Together Skills, (2) Group Reflecting, and (3) Positive Interdependence. The first factor includes 9 items, while the second and third factors each include 4 items. The CLSS is a four-point Likert-type scale with item scores ranging from 1 to 4 and does not contain any negatively worded items. The total possible score ranges from 17 to 68. Reliability analyses using Cronbach's alpha yielded coefficients of .83 for Working Together Skills, .64 for Group Reflecting, and .61 for Positive Interdependence.The overall reliability coefficient for the entire scale was reported as .87 in the original scale development study (Burak, 2020).

Implementation Process

The research process lasted a total of 10 weeks. During the first and last weeks, the Science Attitude Scale (SAS) and the Collaborative Learning Skills Scale (CLSS) were administered to the students. All instructional activities were implemented within the regular science lessons, allocated 3 hours per week for both the experimental and control groups. In the remaining 8 weeks, STEM education was implemented within the scope of the units "Properties of Matter" and "Lighting and Sound Technologies." These topics were chosen because they aligned with the science curriculum during the research period.

The lesson plans, activity guides, and student worksheets were prepared by the researchers. While developing the content, the website "TeachEngineering", which includes a wide range of STEM activities tailored to different grade levels and learning objectives, was used as a resource (https://www.teachengineering.org/). The activities on this site clearly present the integration of science, mathematics, technology, and engineering disciplines. These English-language materials were translated into Turkish and adapted according to the students' comprehension levels and the availability of materials. In all science classes, students were divided into six groups of four students each. During the implementation process, a designated STEM activity was implemented each week through group work, guided by the teacher. Each activity began with an introduction. This section introduced the topic using relevant questions, texts, or real-life scenarios. The group task was then explained, and students were instructed to follow the instructions on the activity worksheet. Students first discussed their ideas within their groups and then completed steps such as design, planning, material selection, and prototype development. Throughout the process, students were encouraged to collaborate, share responsibilities, and make decisions together. At the end of each activity, the groups presented their products to the class and received feedback. Figure 1 summarizes the implemented activities and the corresponding weeks. Figure 2 provides an example of a student activity sheet.

Figure 1.
STEM Education Implementation Process

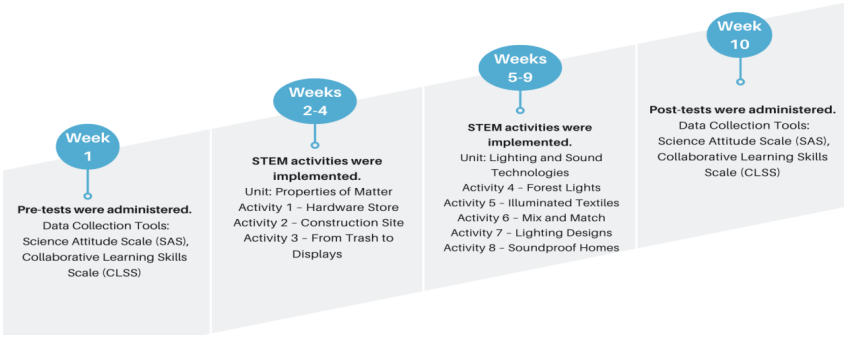


Figure 2.
An example of a student activity sheet from the Soundproof Homes activity.

Post Introduction Activity

Group Brainstorming:

Share your ideas with your group members for your design. Draw your design. Write down all the materials you need and how many of each you will need for your entire soundproof house.

Group design:

After deciding on your design, build a prototype of your soundproof house. Calculate the change in decibels by subtracting the decibel level of the empty house from the level of your completed design. Write your results below.

Before materials: _____

After materials: _____

Change in decibels: _____

After all group readings, answer the questions below:

- Which group had the highest and lowest decibel readings?
- What is the difference in decibel readings between those two groups?
- Why do you think the group with the highest decibel reading got that result? (Consider the materials used.)
- Why do you think the group with the lowest decibel reading got that result? (Consider the materials used.)
- If you could redesign your prototype, what would you change?
- In what other areas could your design be useful?

Data Analysis

Quantitative data in this study were analyzed using the SPSS 23 statistical software package. Prior to analysis, the data were transferred to SPSS 23 and checked for missing values, patterned responses, and outliers to ensure the dataset was ready for analysis. The selection of hypothesis tests was based on the normality of the data distribution. For normality assessment, Z-scores were calculated by dividing the skewness and kurtosis values by their respective standard errors. Following Karagöz (2017), Z-values within the ±2 range were considered indicative of normal distribution. The analyses revealed that the Z-scores for the measurement tools fell within this acceptable range, indicating that the data were generally normally distributed. Therefore, parametric tests were used in the analyses.

In comparing group means, a 95% confidence interval and a .05 significance level were used as benchmarks. Paired Samples t-Test was employed to compare the pre-test and post-test scores within the experimental and control groups, while Independent Samples t-Test was used for between-group comparisons. To evaluate the effect size of significant differences, Cohen's *d* was calculated and interpreted based on Cohen's (1988) guidelines: .20 and below = small effect, .20–.80 = medium effect, and .80 and above = large effect.

RESULTS

In this section, the data obtained during the research process are analyzed and presented systematically to address the main research question and its sub-questions.

Results Related to the Science Attitude Scale (SAS)

Table 2 compares the pre-test mean attitude scores of the experimental group (M = 76.45) and the control group (M = 77.50).

Table 2.

Independent Samples t-Test Results for the Pre-Test Scores on the Science Attitude Scale in the Experimental and Control Groups

Groups	N	M	SD	Df	t	p
Pre-test experimental	24	76.45	7.13	44	.28	0.782
Pre-test control	22	77.50	16.71			

As indicated in Table 2, the analysis revealed that the difference between the two groups was not statistically significant (t = .28, df = 44, p = .782 > .05). Based on this result, it can be concluded that the students in both the experimental and control groups had similar attitudes toward science at the beginning of the study.

Table 3 presents the results of the Paired Samples t-Test for the pre-test and post-test scores of the Science Attitude Scale in both the experimental and control groups.

Table 3.

Paired Samples t-Test Results for Pre-Test and Post-Test Scores on the Science Attitude Scale in the Experimental and Control Groups

Groups	Test	N	M	SD	df	t	p
Experimental	Pre-test	24	76.45	7.13	23	−3.13	.005
	Post-test	24	82.79	7.67			
Control	Pre-test	22	77.50	16.71	21	.17	.65
	Post-test	22	77.00	9.87			

Table 3 shows that in the control group, the post-test mean score slightly decreased compared to the pre-test (M_pre= 77.50, M_post = 77.00); however, this difference was not statistically significant (p = .865 > .05). This finding suggests that the science activities conducted in the non-intervention classroom did not significantly affect students' attitudes toward science. In contrast, the experimental group showed a statistically significant increase in science attitude scores between the pre-test (M = 76.45) and post-test (M = 82.79) (t = – 3.13, df = 23, p = .005 < .05, d = 0.65). These results indicate that the STEM education intervention had a moderately positive effect on students' attitudes toward science.

Table 4 presents the post-test scores on the Science Attitude Scale for both the experimental and control groups.

Table 4.

Independent Samples t-Test Results for the Post-Test Scores on the Science Attitude Scale in the Experimental and Control Groups

Groups	N	M	SD	Df	t	p
Post-test experimental	24	82.79	7.67	44	2.20	.033
Post-test control	22	77.00	9.87			

As indicated in Table 4, the mean post-test score of the experimental group (M = 82.79) was slightly higher than that of the control group (M = 77.00). This difference was statistically significant (t = 2.20, df = 44, p = .033 < .05, d = 0.33), favoring the experimental group. These results indicate that the STEM education intervention had a more positive effect on students' science attitudes compared to the instructional practices used in the existing curriculum.

Results Related to the Collaborative Learning Skills Scale (CLSS)

Table 5 compares the pre-test mean collaborative learning skills scores of the experimental group (M = 48.62) and the control group (M = 49.81).

Table 5.

Independent Samples t-Test Results for the Pre-Test Scores on the Collaborative Learning Skills Scale in the Experimental and Control Groups

Groups	N	M	SD	Df	t	P
Pre-test experimental	24	48.62	9.88	44	-.47	.636
Pre-test control	22	49.81	6.63			

As shown in Table 5, there was a slight difference between the pre-test mean scores of the experimental group (M_{exp}.= 48.62) and the control group (M_{cont}.= 49.81) regarding collaborative learning skills. However, this difference was not statistically significant (t = – 0.47, df = 44, p = .636 > .05). Based on this result, it can be concluded that the collaborative learning skills of students in both the experimental and control groups were at similar levels at the beginning of the study.

Table 6 presents the pre-test scores for collaborative learning skills in both the experimental and control groups.

Table 6.

Independent Samples t-Test Results for the Pre-Test Scores on the Collaborative Learning Skills Scale in the Experimental and Control Groups

Groups	N	M	SD	Df	t	p
Pre-test experimental	24	48.62	9.88	44	-.47	.636
Pre-test control	22	49.81	6.63			

According to Table 6, there was a slight difference between the pre-test mean scores of the experimental group (M = 48.62) and the control group (M = 49.81) regarding collaborative learning skills; however, this difference was not statistically significant (t = – 0.47, df = 44, p = .636 > .05). This result indicates that the collaborative learning skills of students in both groups were at comparable levels at the start of the study.

Table 7 presents the pre-test and post-test scores for the Collaborative Learning Skills Scale in both the experimental and control groups.

Table 7.

Paired Samples t-Test Results for Pre-Test and Post-Test Scores on the Collaborative Learning Skills Scale in the Experimental and Control Groups

Groups	Test	N	M	SD	df	t	p
Experimental	Pre-test	24	48.62	9.88	23	-2.16	.041
	Post-test	24	53.20	5.36			
Control	Pre-test	22	49.81	6.63	21		
	Post-test	22	49.68	8.23			

As shown in Table 7, in the control group, a small difference was observed between the pre-test (M = 49.81) and post-test (M = 49.68) mean scores; however, this difference was not statistically significant (p = .936 > .05). This indicates that the traditional science instruction did not significantly affect students' collaborative learning skills. In contrast, the experimental group showed a statistically significant increase between the pre-test (M = 48.62) and post-test (M = 53.20) scores (t = – 2.16, df = 23, p = .041 < .05), indicating that STEM-based instructional practices positively influenced students' collaborative learning skills.

Table 8 presents the post-test scores on the Collaborative Learning Skills Scale for both the experimental and control groups.

Table 8.

Independent Samples t-Test Results for the Post-Test Scores on the Collaborative Learning Skills Scale in the Experimental and Control Groups

Groups	N	M	SD	Df	t	p
Post-test experimental	24	53.20	5.36	44	1.73	.090
Post-test control	22	49.68	8.23			

As indicated in Table 8, The mean post-test score of the experimental group (M = 53.20) was higher than that of the control group (M = 49.68). However, this difference was not statistically significant (p = .090 > .05). This result indicates that the collaborative learning skills of students in the experimental group were similar to those in the control group (Table 7).

Results Related to the Sub-Dimensions of the Collaborative Learning Skills Scale (CLSS)

Table 9 presents the pre-test and post-test scores of the control group in the sub-dimensions of the Collaborative Learning Skills Scale.

Table 9.

Paired Samples t-Test Results for the Pre-Test and Post-Test Scores on the Sub-Dimensions of the Collaborative Learning Skills Scale (CLSS) in the Control Group

Factors	Test	N	M	SD	df	t	p
Positive Interdependence	Pre-test	22	11.81	2.38	21	-.22	.825
	Post-test	22	11.95	2.85			
Group Reflecting	Pre-test	22	10.90	3.03	21	.34	.731
	Post-test	22	10.63	2.17			
Working Together Skills	Pre-test	22	28.31	3.79	21	1.02	.319
	Post-test	22	27.50	5.18			

As shown in Table 9, although there were minor differences between the pre-test and post-test mean scores of the control group in Positive interdependence (Mpre = 11.81, Mpost = 11.95, t = –0.22, df = 21, p = .825), Group Reflecting (Mpre = 10.90, Mpost = 10.63, t = 0.34, df = 21, p = .731), and Working together skills (Mpre = 28.31, Mpost = 27.50, t = 1.02, df = 21, p = .319), none of these differences were statistically significant (p > .05). These results indicate that the existing instructional practices did not significantly impact the control group students' collaborative learning skills in these sub-dimensions.

Table 10 presents the pre-test and post-test scores of the experimental group in the sub-dimensions of the Collaborative Learning Skills Scale.

Table 10.

Paired Samples t-Test Results for the Pre-Test and Post-Test Scores on the Sub-Dimensions of the Collaborative Learning Skills Scale (CLSS) in the Experimental Group

Factors	Test	N	M	SD	df	t	p
Positive Interdependence	Pre-test	24	11.79	2.71	23	-3.71	.001
	Post-test	24	13.91	1.97			
Group Reflecting	Pre-test	24	10.25	2.99	23	-1.07	.292
	Post-test	24	11.00	2.14			
Working Together Skills	Pre-test	24	26.58	5.58	23	-1.43	.164
	Post-test	24	28.20	3.69			

Table 10 shows that the experimental group exhibited increases in Positive interdependence (Mpre = 11.79, Mpost = 13.91, t = – 3.71, df = 23, p = .001), Group Reflecting (Mpre = 10.25, Mpost = 11.00, t = – 1.07, df = 23, p = .292), and Working together skills (Mpre = 26.58, Mpost = 28.20, t = – 1.43, df = 23, p = .164). However, this increase reached statistical significance only in the Positive Interdependence sub-dimension ($p < .05$). These results suggest that STEM education interventions positively affected students' collaborative learning skills, particularly in fostering Positive Interdependence.

Table 11 presents the post-test scores of the experimental and control groups in the sub-dimensions of the Collaborative Learning Skills Scale.

Table 11.

Independent Samples t-Test Results for the Post-Test Scores on the Sub-Dimensions of the Collaborative Learning Skills Scale (CLSS) in the Experimental and Control Groups

Factors	Groups	N	M	SD	df	t	p
Positive Interdependence	Experimental	24	13.91	1.97	44	2.68	.011
	Control	22	11.95	2.85			
Group Reflecting	Experimental	24	11.00	2.14	44	.57	.571
	Control	22	10.63	2.17			
Working Together Skills	Experimental	24	28.20	3.69	44	.53	.599
	Control	22	27.50	5.18			

According to Table 11, the post-test scores of the experimental group (M = 13.91) were significantly higher than those of the control group (M = 11.95) in the positive interdependence sub-dimension (t = 2.68, df = 44, p = .011, d = 0.40), suggesting that STEM education effectively fostered students' cooperative dependency on group success. However, no statistically significant differences were found between the groups in the Group Reflecting (Mexp. = 11.00, Mcont. = 10.63, t = 0.57, df = 43.55, p = .571) or Working together skills (Mexp. = 28.20, Mcont. = 27.50, t = 0.53, df = 37.67, p = .599) sub-dimensions ($p > .05$), suggesting that students in both groups exhibited similar levels in these sub-dimensions after the interventions.

CONCLUSION AND DISCUSSION

This study examined the effects of STEM-based instructional practices on disadvantaged elementary students' attitudes toward science and their collaborative learning skills. The results indicate that STEM education had a clear and significant effect on students' science attitudes, whereas its impact on collaborative learning skills was more limited and dimension-specific.

The results revealed that STEM education had a strong and positive influence on students' attitudes toward science. While traditional science instruction did not lead to meaningful changes in students' science attitudes, students who participated in STEM-based activities demonstrated more positive attitudes at the end of the intervention. The medium effect size obtained suggests that this change was not only statistically significant but also educationally meaningful. This finding implies that conventional instructional approaches may be insufficient in fostering positive science attitudes among disadvantaged students who experience language barriers, limited academic support, or adaptation difficulties. One possible explanation lies in the interdisciplinary and application-oriented nature of STEM education. STEM activities encourage students to actively engage with real-life problems, relate scientific concepts to everyday experiences, and take responsibility for their own learning processes (Capraro & Jones, 2013). Gillies (2023) emphasized the close relationship between inquiry-based science learning and cooperative learning environments. Such environments foreground students' active participation, shared responsibility, and social interaction in the process of knowledge construction. These characteristics offer important advantages, particularly for disadvantaged students who may struggle with abstract, text-based, or teacher-centered instruction. Learning environments grounded in hands-on exploration and problem-solving may help students perceive science as more accessible, meaningful, and connected to real life. These results are consistent with previous studies reporting that STEM-based instruction positively influences students' attitudes toward science and enhances interest and motivation (Bybee, 2013; Gazibeyoğlu & Aydın, 2020; Seçgin & Sungur, 2021). Gazibeyoğlu and Aydın (2020) reported a significant improvement in seventh-grade students' attitudes toward science following STEM-supported instruction. Güvenç, and Altun-Yalçın (2020) also found that STEM-based education increased migrant students' interest in science, fostered curiosity, and supported collaboration skills. Supporting these results at a broader level, the meta-analysis conducted by Hikmah et al. (2025) demonstrated that STEM approaches make substantial contributions to affective learning outcomes and science attitudes. The positive changes in science attitudes observed in the present study are especially noteworthy in the context of disadvantaged and migrant students. For these groups, developing positive attitudes toward science at an early age may serve as a critical foundation for long-term engagement, academic continuity, and future participation in STEM learning opportunities.

Despite the strong results related to science attitudes, the results regarding collaborative learning skills indicate a more limited effect at the overall score level. STEM activities did not result in a statistically significant difference in students' overall collaborative learning skills compared to the control group. This suggests that although STEM-based instruction has the potential to support collaborative learning, the duration and context of the present intervention may not have been sufficient for this effect to become clearly distinguishable from traditional instructional practices.

Several factors may account for this result. First, the development of complex social skills such as collaboration often requires sustained and long-term practice. In addition, the occasional use of group work activities by the teacher in the control group may have reduced observable differences between groups. Consistent with this interpretation, previous studies have reported positive trends in collaborative learning skills that do not always reach statistically significant differences between instructional conditions (Bakan & Bircan, 2025).

Although no significant difference was found in the overall collaborative learning score, one of the most notable results of this study was the significant effect of STEM education on the positive interdependence sub-dimension. Students who participated in STEM activities demonstrated higher scores on positive interdependence, encompassing items such as working harmoniously with group members and prioritizing group success, compared to their peers in the control group. This finding suggests that STEM learning environments may be particularly effective in fostering a sense of succeeding together, which constitutes a core element of collaborative learning. Johnson et al. (1994) emphasize that when positive interdependence is established, students become more open to one another's ideas, develop mutual trust, and show greater willingness to work together toward group success. In this respect, it may be suggested that the STEM activities implemented in this study, requiring students to collaboratively analyze real-life problems, generate solutions, and produce shared outcomes, strengthened students' perceptions that individual success is closely linked to group success, thereby supporting positive interdependence. The literature similarly highlights that STEM-based practices support not only students' cognitive development but also their social and emotional growth (Lamb et al., 2015; Kim et al., 2014; Cinar et al., 2016). Chen et al. (2023) noted that STEM education contributes to the development of collaboration and communication skills through structured group work. Similarly, Karakaya et al. (2019) emphasized that STEM activities contribute to communication skills. This finding is particularly meaningful for disadvantaged students. In this context, collaborative learning experiences may enhance students' social interactions and create opportunities for developing supportive peer relationships. Likewise, Leyva et al. (2021) argued that promoting collaboration and allowing students to build supportive peer relationships can help reduce social isolation.

While a significant improvement was observed in the positive interdependence sub-dimension, the absence of similar changes in other sub-dimensions, such as working together skills and group reflecting, suggests that the STEM activities implemented in this study primarily activated the foundational components of collaborative learning. In the literature, positive interdependence is often described as the "heart" of cooperative learning and is considered the first and most essential component of the collaborative process (Johnson et al., 1994; page. 5). Once positive interdependence is established, teachers are better positioned to enhance opportunities for students to support and encourage one another's learning and to reflect on each other's contributions and success (Johnson et al., 1994; page. 6). Gillies (2023) emphasized that social skills related to working together do not develop automatically and that teachers must explicitly structure how students interact respectfully and appropriately within groups. Similarly, group processing and reflecting requires students to evaluate group interactions, recognize behaviors that contribute to group success, and make collective

decisions about improvement, rendering it a more complex competency by nature (Johnson & Johnson, 2014; Johnson & Johnson, 2002). From this perspective, the more pronounced effect of STEM activities on positive interdependence observed in the present study appears consistent with theoretical expectations. For meaningful changes to emerge in complex collaborative skills such as working together skills and group reflecting, STEM-based learning environments may need to be implemented over longer periods and supported by systematic pedagogical structures that explicitly target these skills. Therefore, further empirical studies are needed to examine in greater detail the effects of STEM education on different sub-dimensions of collaborative learning.

In conclusion, the results of this study demonstrate that STEM education is effective in strengthening students' attitudes toward science and in supporting certain dimensions of collaborative learning, particularly positive interdependence. Despite the limited effects observed in overall collaborative learning skills, the significant improvement in positive interdependence clearly highlights the social and emotional potential of STEM-based learning environments. In this respect, STEM education represents not only an approach that supports science learning for disadvantaged students but also an inclusive pedagogical framework that fosters positive peer relationships.

Limitations and Future Research

This study provides evidence regarding the effects of STEM-based activities on disadvantaged elementary students' science attitudes and collaborative learning skills. However, several limitations should be acknowledged, and these limitations offer directions for future research. First, to more clearly identify the effects of STEM educational interventions, it is important to design long-term and sustainable implementation programs. Longer interventions would allow researchers to more accurately track changes in students' attitudes, skills, and academic achievement over time. Second, the present study focused on disadvantaged students under temporary protection status and those from low socioeconomic backgrounds. Future studies may examine similar STEM interventions with student groups from different socioeconomic levels, cultural backgrounds, or learning needs to assess the generalizability of the results. Finally, this study found that STEM activities particularly enhanced students' levels of positive interdependence within collaborative learning environments. Accordingly, future research is encouraged to design studies that empirically examine more specific sub-dimensions of collaborative learning skills, such as group processing and reflecting, task sharing, and working together social processes, in greater depth. Such studies would contribute to a clearer understanding of which dimensions of collaborative learning are supported by STEM-based environments, under what conditions, and to what extent.

Endnotes: The Collaborative Learning Skills Scale used in this study was originally developed in Turkish (Burak, 2020). The English labels of the subscales were determined by the third author of this article, who is also the developer of the original scale, and are used consistently throughout the manuscript.

Data Availability Statement: The datasets generated or analyzed during the current study are available from the authors upon reasonable request.

Use of Artificial Intelligence: In this study, AI tools were used solely for language and grammar checking; no AI tools were employed for analysis, data generation, interpretation of results, or scientific reasoning. The overall use of AI did not exceed 20%.

Ethical Statement: This research was conducted under the ethical committee approval of Kilis 7 Aralık University Rectorate Ethics Committee, with decision number 2023/19 dated 06.11.2023.

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STEM Eğitiminin Dezavantajlı İlkokul Öğrencileri Üzerindeki Etkisi: Fen Tutumları ve İşbirlikli Öğrenme Becerileri

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Giriş

Bilim, teknoloji, mühendislik ve matematik alanlarında nitelikli insan gücüne duyulan gereksinimin giderek artmasına karşın öğrencilerin STEM alanlarına yönelimlerinde yaşanan düşüş, eğitim sistemlerinin öğrencilerde fen bilimlerine yönelik olumlu tutumlar geliştirmesini daha önemli hâle getirmiştir (Summers & Abd-El-Khalick, 2018). Günümüzde eğitim yalnızca bilgi aktarımını değil, aynı zamanda bireylerin problem çözme, eleştirel düşünme, iletişim kurma ve iş birliği yapma gibi 21. yüzyıl becerilerini geliştirmeyi amaçlamaktadır (Murnawianto & Rahardjo, 2019). Bu bağlamda STEM eğitimi, öğrencilerin disiplinlerarası bakış açısı kazanmalarına ve gerçek yaşam problemlerine yönelik çözümler üretmelerine olanak sağlayan etkili yaklaşımlardan biri olarak görülmektedir (Kuo vd., 2019).

STEM eğitiminin temel özelliklerinden biri işbirlikli öğrenme süreçlerini desteklemesidir. STEM etkinlikleri sırasında öğrencilerden gerçek yaşam problemlerini birlikte analiz etmeleri, çözüm yolları geliştirmeleri ve ortak ürünler ortaya koymaları beklenmektedir (Capraro & Jones, 2013). Bu süreçler öğrencilerin hem akademik hem de sosyal gelişimlerini desteklemektedir. Özellikle farklı sosyoekonomik ve kültürel geçmişlerden gelen öğrencilerin bir arada bulunduğu sınıflarda işbirlikli öğrenme, öğrencilerin akranlarıyla etkileşim kurmalarına ve öğrenme süreçlerine daha aktif katılmalarına katkı sağlamaktadır (Leyva vd., 2021).

Son yıllarda STEM eğitiminin dezavantajlı öğrencilere sağlayabileceği katkılar daha fazla dikkat çekmektedir. Göç, düşük sosyoekonomik düzey, dil engelleri ve eğitim olanaklarına erişimde yaşanan güçlükler öğrencilerin akademik ve sosyal gelişimlerini olumsuz etkileyebilmektedir (Howie et al., 2008). Türkiye'de özellikle geçici koruma altındaki Suriyeli öğrenciler ve düşük gelirli ailelerden gelen öğrenciler

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önemli bir dezavantajlı grup oluşturmaktadır. Araştırmalar STEM temelli öğrenme ortamlarının bu öğrencilerin fen bilimlerine yönelik ilgilerini artırabildiğini ve işbirliği becerilerini destekleyebildiğini göstermektedir (Güven & Altun-Yalçın, 2020; Yalçın vd., 2022). Bununla birlikte ilkokul düzeyindeki dezavantajlı öğrenciler üzerinde yürütülen çalışmaların sınırlı olduğu görülmektedir. Bu doğrultuda araştırmada STEM temelli öğretim uygulamalarının dezavantajlı ilkokul öğrencilerinin fen bilimlerine yönelik tutumları ve işbirlikli öğrenme becerileri üzerindeki etkisinin incelenmesi amaçlanmıştır.

Yöntem

Araştırmada nicel araştırma yöntemlerinden yarı deneysel desen kullanılmıştır. Çalışma ön test-son test kontrol gruplu deneysel desen doğrultusunda yürütülmüştür (Creswell & Creswell, 2017). Araştırma Türkiye'nin güneydoğusunda bulunan bir devlet ilkokulunda gerçekleştirilmiştir. Katılımcılar uygun örnekleme yöntemiyle belirlenmiş olup toplam 46 dördüncü sınıf öğrencisinden oluşmaktadır. Deney grubunda 24, kontrol grubunda ise 22 öğrenci yer almıştır.

Araştırmada veri toplama aracı olarak Fen Tutum Ölçeği (Tosun & Genç, 2015) ile İşbirlikli Öğrenme Becerileri Ölçeği (Burak, 2020) kullanılmıştır. Araştırma süreci toplam on hafta sürmüştür. İlk ve son haftalarda ön test ve son test uygulamaları gerçekleştirilmiştir. Aradaki sekiz haftalık süreçte deney grubunda STEM etkinlikleri yürütülürken kontrol grubunda mevcut öğretim programı doğrultusunda öğretim faaliyetleri sürdürülmüştür. STEM uygulamaları "Maddenin Özellikleri" ve "Aydınlatma ve Ses Teknolojileri" üniteleri kapsamında gerçekleştirilmiştir. Öğrenciler küçük gruplar hâlinde çalışmış, tasarım geliştirme, problem çözme, malzeme seçimi ve ürün oluşturma süreçlerine aktif olarak katılmışlardır.

Verilerin analizinde SPSS 23 programı kullanılmıştır. Normal dağılım varsayımının sağlanması nedeniyle parametrik testlerden yararlanılmıştır. Grup içi karşılaştırmalarda bağımlı örneklemler t-testi, gruplar arası karşılaştırmalarda ise bağımsız örneklemler t-testi kullanılmıştır. Anlamlı farklılıkların etki büyüklükleri Cohen'in d katsayısı ile hesaplanmıştır.

Bulgular

Araştırma öncesinde deney ve kontrol gruplarının fen bilimlerine yönelik tutum puanları arasında anlamlı bir farklılık bulunmamıştır ($t = .28$, $p = .782$). Bu sonuç, iki grubun araştırma başlangıcında benzer özelliklere sahip olduğunu göstermektedir.

Fen tutumuna ilişkin grup içi karşılaştırmalar incelendiğinde, kontrol grubunun ön test ve son test puanları arasında anlamlı bir farklılık bulunmamıştır ($t = .17$, $p = .865$). Buna karşılık deney grubunda STEM uygulamaları sonrasında fen tutumu puanlarının anlamlı düzeyde arttığı belirlenmiştir. Deney grubunun fen tutumu puan ortalaması ön testte 76.45 iken son testte 82.79'a yükselmiştir ($t = – 3.13$, $p = .005$, $d = .65$). Son test puanları bakımından deney grubu lehine anlamlı bir farklılık bulunmuştur ($t = 2.20$, $p = .033$, $d = .33$).

İşbirlikli öğrenme becerilerine ilişkin ön test sonuçları incelendiğinde deney ve kontrol grupları arasında anlamlı bir farklılık olmadığı görülmüştür ($t = – .47$, $p = .636$). Uygulama sonrasında deney grubunun toplam işbirlikli öğrenme puanlarında anlamlı bir artış belirlenmiştir. Deney grubunun puan ortalaması

48.62'den 53.20'ye yükselmiştir (t = – 2.16, p = .041). Bununla birlikte son test puanları açısından deney ve kontrol grupları arasındaki fark istatistiksel olarak anlamlı bulunmamıştır (t = 1.73, p = .090).

İşbirlikli öğrenme becerilerinin alt boyutları incelendiğinde, deney grubunda yalnızca pozitif bağlılık boyutunda anlamlı bir gelişim ortaya çıkmıştır. Pozitif bağlılık puanları ön testte 11.79 iken son testte 13.91'e yükselmiştir (t = – 3.71, p = .001). Son test puanları bakımından da deney grubu lehine anlamlı bir farklılık belirlenmiştir (t = 2.68, p = .011, d = .40). Buna karşılık grup değerlendirme ve birlikte çalışma becerileri boyutlarında anlamlı farklılık bulunmamıştır.

Tartışma ve Sonuç

Araştırma sonuçları STEM temelli öğretim uygulamalarının dezavantajlı ilkokul öğrencilerinin fen bilimlerine yönelik tutumlarını geliştirmede etkili olduğunu göstermektedir. Bu sonuç STEM eğitiminin öğrencileri gerçek yaşam problemleriyle karşı karşıya getiren, aktif katılımı teşvik eden ve öğrenmeyi somut deneyimlerle destekleyen yapısıyla açıklanabilir (Capraro & Jones, 2013). STEM etkinlikleri sırasında öğrencilerin problem çözme süreçlerine doğrudan katılması, bilimsel kavramları günlük yaşamla ilişkilendirmesi ve öğrenme sürecinde aktif rol üstlenmesi fen bilimlerine yönelik olumlu tutumların gelişmesine katkı sağlamış olabilir. Elde edilen bulgular STEM uygulamalarının öğrencilerin fen tutumlarını olumlu yönde etkilediğini ortaya koyan çalışmalarla tutarlıdır (Bybee, 2013; Gazibeyoğlu & Aydın, 2020; Seçgin & Sungur, 2021). Ayrıca Güven ve Altun-Yalçın'ın (2020) göçmen öğrencilerle yürüttüğü araştırmanın sonuçlarıyla da benzerlik göstermektedir.

İşbirlikli öğrenme becerilerinin toplam puanında gruplar arasında anlamlı bir farklılığın bulunmaması, bu becerilerin gelişiminin daha uzun süreli ve sistematik uygulamalar gerektirdiğini düşündürmektedir. Bununla birlikte pozitif bağlılık alt boyutunda ortaya çıkan anlamlı gelişim dikkat çekicidir. Johnson et al. (1994) göre pozitif bağlılık işbirlikli öğrenmenin temel bileşenlerinden biridir ve öğrencilerin kendi başarılarını grup başarısıyla ilişkilendirmelerini ifade etmektedir. STEM etkinlikleri sırasında öğrencilerin ortak ürünler geliştirmeleri, grup kararları almaları ve görev paylaşımı yapmaları bu boyutun gelişmesine katkı sağlamış olabilir.

Araştırmada grup değerlendirme ve birlikte çalışma becerileri boyutlarında anlamlı farklılıkların ortaya çıkmaması, işbirlikli öğrenmenin daha karmaşık bileşenlerinin gelişebilmesi için daha uzun süreli uygulamalara ihtiyaç duyulduğunu göstermektedir. Gillies (2023) ve Johnson ve Johnson (2002, 2014), işbirlikli öğrenme becerilerinin kendiliğinden gelişmediğini ve öğretmenler tarafından sistematik biçimde desteklenmesi gerektiğini vurgulamaktadır. Bu nedenle gelecekte gerçekleştirilecek araştırmalarda daha uzun süreli STEM uygulamalarının işbirlikli öğrenmenin farklı boyutları üzerindeki etkilerinin incelenmesi önerilmektedir.

Sonuç olarak araştırma, STEM temelli öğretim uygulamalarının dezavantajlı ilkokul öğrencilerinin fen bilimlerine yönelik tutumlarını geliştirmede etkili olduğunu ve işbirlikli öğrenmenin özellikle pozitif bağlılık boyutunu desteklediğini ortaya koymuştur. Bu yönüyle STEM eğitimi yalnızca akademik öğrenmeyi destekleyen bir yaklaşım değil, aynı zamanda öğrencilerin sosyal etkileşimlerini güçlendiren ve kapsayıcı öğrenme ortamları oluşturan önemli bir pedagojik çerçeve olarak değerlendirilebilir.