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The Impact of the STEM-Integrated Learning Model on Students' Academic Achievement and Attitudes Towards Science Courses

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ABSTRACT

This study examines the effects of integrating STEM activities into the science curriculum on students’ academic achievement in the circulatory system topic and their attitudes toward science. This study was designed as a quantitative research and implemented using a pretest–posttest control group quasi-experimental design. This design is commonly employed in experimental research, as it s considered to provide a means to establish valid causal relationships through the control of extraneous variables. The study sample consisted of 40 sixth-grade students (Experimental group = 20 Control group = 20) from a middle school in Erzurum province during the 2022-2023 academic year. In the study, the Circulatory System Academic Achievement Test (CSAT) and the Attitude Scale Toward Science Course (ASSC) were employed to assess students' academic achievement and attitudes toward the science course. Following data collection, statistical analyses were conducted to examine group differences. T-tests, one-way analysis of variance (ANOVA), and analysis of covariance (ANCOVA) were conducted. Based on the analysis results, the derived findings were systematically organized into tables and subsequently interpreted in a comprehensive manner. An effect size was also calculated for the ASSC. The research findings indicate a statistically significant difference in academic achievement between the experimental and control groups, favoring the experimental group. However, no statistically significant difference was observed in students' attitudes toward the science course.

Keywords: Circulatory system, attitudes towards science course, STEM activity.

Introduction

Recent advancements in science and technology have necessisated contionus updates in educational curricula worlwide. Countries that prioritize science and mathematics education have a leader role in scientific and technological competition. Consequently, new advancements and developments in science, technology, and engineering are essential not only for fostering economic and meaningful progress, but also for maintaining continuity in the globalization process.

In recent years, rapid advancements in technology have led to changes in many fields, including education. Since 2005, educational programs have significant shift from traditional approaches to constructivist paradigms, which emphasize student-centered learning. Additionally, according to the 2018 Science Education Program by Turkey's National Ministry of Education (MEB), there has been an emphasis on cultivating individuals with 21st-century skills (Erkan, 2023).

The updated science curriculum encourages students to take responsibility for addressing real-world problems by applying scientific knowledge, scientific process skills, and essential life competencies. The rapid advancement of science and technology plays a significant role in shaping societal development and transformation, further emphasizing the importance of science education. Consequently, many countries continuously evaluate and revise their education systems and science curricula to meet emerging needs. In Türkiye, educational programs have been adapted to align with contemporary demands. One effective approach to improving the efficiency of science education is the integration of STEM principles, fostering interdisciplinary connections. This integration promotes a deeper understanding of scientific processes and enhances inquiry-based learning, allowing students to engage in problem-solving within knowledge-driven contexts (Değerli, 2021).

Similarly, in Türkiye, the science curriculum introduced in 2018 aligns with global transformations, emphasizing students’ ability to establish connections between science and engineering while fostering entrepreneurial practices. In this regard, individuals must develop an interdisciplinary perspective to acquire 21st-century skills in addition to their foundational competencies. Achieving an interdisciplinary perspective is made possible through the integration of science, mathematics, technology, and engineering disciplines, enabling a more holistic approach to learning. This framework has led to the design of STEM activities, which represent innovative and application-based practices in science education (Toprak, 2021).

STEM education employs an interdisciplinary approach that integrates academic concepts within real-life contexts by applying science, technology, engineering, and mathematics. This integrated learning framework fosters connections between schools, communities, industries, and global organizations, thereby preparing students for the evolving economic landscape. STEM learning encompasses various approaches that engage two or more STEM disciplines. When effectively structured, STEM education facilitates meaningful learning through the integration and application of mathematics, technology, and science (Permanasari et al., 2021).

The term STEM, derived from the initials of Science, Technology, Engineering, and Mathematics, has become synonymous with a distinct educational approach. Within the STEM education framework, various disciplines converge to address learning challenges through integrated solutions. Moreover, STEM education embraces a philosophy that seeks to cultivate 21st-century skills by fostering an interdisciplinary perspective rooted in the synthesis of science, technology, engineering, and mathematics. (Ünlü, 2022).

In other words, science, technology, engineering, and mathematics (STEM) constitute a meta-discipline, which represents an educational approach premised on synthesizing knowledge from diverse disciplines into a cohesive "whole." This conceptual bridge between distinct disciplines is recognized as STEM (Morrison, 2006). Furthermore, from an alternative standpoint, numerous STEM educators and researchers interpret the acronym STEM as a representation of the interconnectedness inherent within four foundational disciplines. Crucially, this interconnectedness does not imply the constant integration of these disciplines, but rather strategic and pedagogically meaningful connections aligned with learning goals. (Jones, et al., 2020).

STEM-related studies have gained significant momentum in fostering students' positive attitudes towards science and enhancing their motivation to pursue careers in science-related fields. The fundamental principle of STEM education lies in the systematic integration and coordinated application of science, technology, engineering, and mathematics domains, emphasizing problem-solving at its core. Consequently, STEM education serves as a pedagogical framework that underscores the importance of acquiring, promoting, and advancing the disciplines denoted by the acronym. (Toma & Greca, 2018).

The integration of STEM into education entails dismantling barriers between disciplines, fostering a deeper conceptual understanding and enhanced academic performance in STEM-related areas, and cultivating an appreciation for the interconnectedness between subjects and real-world challenges. Given its transformative impact on the general student population, STEM education has garnered increasing attention from researchers over the past decade (De Loof et al., 2022).

STEM-based activities can be designed to be hands-on, inquiry-based, and project-based, offering students the opportunity to explore STEM concepts (Prajuabwan & Worapun, 2023). Additionally, STEM education can be defined as the practical application and transformation of the knowledge provided in schools into products. In this sense, it is an approach that allows students to find solutions to daily problems. Rather than treating each discipline in isolation, STEM education provides multiple disciplines to be integrated and processed together, expecting students to find solutions to the problems presented to them using this approach. During the STEM education process, connecting with existing prior knowledge, ensuring meaningful learning, and acquiring higher-order thinking skills are among the advantages of STEM (Topbaş, 2023).

The practical application of STEM education in real life increases students' interest and understanding. It is a strategy that encourages world-class scientific and technological talent by developing convergent thinking and problem-solving skills (Kim & Choi, 2012). The complex challenges that the world faces today cannot be addressed within a single disciplinary framework therefore, they necessitate the integration of multiple fields of knowledge. While interdisciplinary learning is not exclusive to STEM, STEM education enables meaningful and innovative applications that reflect the increasingly interconnected nature of real-world problems.

Mathematical reasoning and problem-solving, as core components of mathematics, are essential in science and technology education. A 21st-century educational approach structures the learning of science, mathematics, and technology within real-life problem contexts, thereby enhancing the relevance and applicability of knowledge.

Moreover, students engaged in STEM learning benefit from collaborative environments where knowledge is constructed through dialogue, discussion, and exchange (Sulueman, 2020). Overall, STEM-oriented classrooms support students' communication, collaboration, and multidimensional thinking skills from an early age.

The contemporary educational philosophy of the current century adopts a process where students are at the center, individual differences are valued, and learners are active. Upon reviewing the literature related to STEM, it is observed that the studies are associated with areas such as argumentation-based, station technique, project-based, educational game-supported, creative drama method, and flipped learning model. In addition to these studies, research on Arduino applications, robotic STEM applications, digital game-based and educational robotic applications have also been encountered (Aluç, 2024; Bekereci, 2022; Demirci, 2023; Eren, 2024; Erkan, 2023; İnce, 2024; Koca, 2023; Özçelik, 2021; Sarıçam, 2019; Uçar, 2019).

To meet the constantly changing needs of society and bring the significantly altered educational understanding into classroom environments compared to the past, one of the widely implemented STEM activities is the use of Scratch program. Scratch, developed by the Massachusetts Institute of Technology (MIT) in the United States, is a programming language with a user-friendly interface specifically designed for children aged 8 to 16. Unlike conventional programming languages, it enables users to generate animations, games, and other interactive projects by simply clicking and dragging the desired functions with their mouse. This feature eliminates the need for complex coding, making Scratch particularly accessible for beginners and widely utilized for educational purposes (https://boenstitu.com/blog/scratch-nedir). The Scratch program is an application related to robotics and coding in STEM education and is widely used in technology, design, engineering, and mathematics fields in robotics coding education (Keçeci, 2018; Yalçın & Akbulut, 2021).

Upon reviewing the literature, various methods and techniques are used in the teaching of the circulatory system. These methods and techniques include project-based learning, argumentation-focused activities, inquiry-based learning, the station technique, mind mapping technique, critical thinking, scaffolded instruction, the use of analogies, open-ended questions, and drawings (Bastem, 2012; Biçer, 2011; Cömert, 2014; Çakıcı, 2019; Fancovicova & Prokop, 2019; Gülbahar, 2023; Kılıç, 2009; Wicaksana et al., 2020; Wulandari et al., 2022; Yalçınkaya, 2018). Additionally, virtual reality applications, animations, augmented reality, interactive digital storytelling, digital educational games, augmented reality, and the structure-behavior-function model are also methods used in teaching the circulatory system (Akkiren, 2019; Demir, 2023; Gnidovec et al., 2020; İlkay, 2022; Sarıçam, 2019; Yeşiltaş, 2019; Yetişir, 2019).

The "Circulatory System," with its concepts (systemic circulation, arteries, veins, etc.), is a topic that students struggle to fully grasp and visualize in their minds. Therefore, it makes it difficult for 6th-grade middle school students, who are still in the concrete operational stage, to learn the topic meaningfully. To enable students to learn meaningfully without resorting to rote learning and to support the development of their social, emotional, and spatial abilities during the learning process, STEM applications have been integrated into the lessons in this study.

Purpose of the Study

This study aims to investigate the effects of integrating STEM activities particularly through the use of Scratch programming—into the science curriculum on sixth-grade students' academic achievement in the circulatory system topic and their attitudes toward science. While Keçeci (2018) reported that Scratch-based instruction significantly enhanced students' academic performance on the circulatory system, changes in student profiles and instructional practices over time necessitate a renewed investigation. Accordingly, this study explores whether STEM-integrated instruction differs from traditional program-based teaching in terms of its impact on students' achievement and attitudes. Therefore, the following question and sub-problems were investigated: "Does teaching the 'Circulatory System' topic within the 6th-grade science curriculum using STEM-integrated instruction and program-based instruction affect students' academic achievement regarding the circulatory system and their attitudes towards the science course?"

Sub-Problems and research questions:

1. Is there a significant difference in the academic achievement on the circulatory system between students who receive STEM-integrated instruction and those who receive program-based instruction?

2. Is there a significant difference in the attitudes towards the science course between students who receive STEM-integrated instruction and those who receive program-based instruction?

Method

Research Model

In this study, a quasi-experimental design with pretest-posttest control groups, one of the experimental research models, was employed to examine the impact of STEM-integrated instruction on students' academic achievement regarding the circulatory system and their attitudes towards the science course. In the pretest-posttest control group model, there are two groups formed through random assignment. One of these groups is assigned as the experimental group, and the other as the control group. Measurements are taken in both groups before and after the experiment (Karasar, 2011). Before the intervention, the Circulatory System Academic Achievement Test (CSAT) and the Attitude Scale towards Science Course (ASSC) were conducted in both the experimental and control groups. In the experimental group, lessons were conducted using STEM applications, specifically Scratch activities, whereas in the control group, lessons were carried out based on the program-oriented instruction model. At the end of the process, the CSAT and ASSC were re-conducted as posttests to both the experimental and control groups. The application plan is shown in Table 1.

Table 1.

The Application Plan

Groups	Pretest	Application	Posttest
Experimental group	CSAT,ASSC	STEM integrated instruction	CSAT,ASSC
Control group	CSAT,ASSC	Program based instruction	CSAT,ASSC

Study Group

The sample of this study comprises 40 sixth-grade students from two different classrooms in Erzurum, Turkey, selected through random assignment during the 2022-2023 academic year. As a result of random selection, one of the classes was assigned as the Experimental Group (EG) (n=20), where lessons were conducted with STEM activities, and the other as the Control Group (CG) (n=20), where lessons were conducted with program-based instruction.

Data Collection Tool

The data collection instruments included the Circulatory System Academic Achievement Test (CSAT) and the Attitude Scale Towards Scence Course (ASSC), both of which have been validated in prior studies.

Circulatory System Academic Achievement Test (CSAT)

While creating the CSAT, questions were prepared by the researcher based on the achievements determined by the Ministry of Education regarding the circulatory system, as the students' success in this topic would be measured. A specification table was created for the questions, and the opinion of an expert actively involved in science education was utilized to ensure the validity of the questions. Revision was made based on the expert's opinion, and the test, consisting of 25 questions, was prepared for pilot application. The CSAT was administered to 140 students at the 7th-grade level for reliability testing. After the pilot study, it was determined that there were no questions negatively affecting reliability. Additionally, the reliability coefficient and item analyses of the CSAT were calculated. The KR-20 reliability coefficient of the CSAT was found to be .838. The reliability of achievement tests is measured through a variety of statistical methods, among which the Kuder-Richardson-20 (KR-20) stands out as a notable technique. KR-20 serves as a measure of internal consistency, specifically designed for tests and scales comprising multiple-choice items.

This method measures a reliability coefficient that ranges from 0 to 1, with values exceeding .70 indicating that the test demonstrates a high level of reliability. Consequently, KR-20 is widely regarded as an effective approach for evaluating the internal coherence and reliability of achievement tests (Demir & Şenyurt, 2021). Based on these results, it can be stated that the CSAT is significantly reliable.

Attitude Scale towards Science Course (ASSC)

The Attitude Scale Toward Science Courses was developed by Taşkın and Aksoy (2019) to measure middle school students' attitudes toward science. It consists of 12 items rated on a 5-point Likert scale, ranging from 'Strongly Disagree' to 'Strongly Agree." During the preparation of the scale items, both a review of the relevant literature and student opinions were utilized. The study employed the descriptive survey method. A probability-based cluster sampling method was used to select participants from the middle school population in Erzurum province. The scale items were administered to 196 middle school students.

To determine the construct validity of the scale, exploratory and confirmatory factor analyses were conducted. In the initial stage of the factor analysis, the data obtained through the implementation of the scale were analyzed using the Kaiser-Meyer-Olkin (KMO) and Bartlett's tests, with the KMO value calculated as .85 and the significance level (p-value) determined as .05. Upon examining the factor loadings and item values through exploratory factor analysis, it was concluded that the scale items could be explained through three primary factors. The first sub-factor, titled "Students' Attitudes Toward the Methods Used in Science Courses," demonstrated a Cronbach's Alpha coefficient of .782. The second sub-factor, "Students' Attitudes Toward the Relevance of Science Courses to Daily Life," had a Cronbach's Alpha coefficient of .718. The third sub-factor, "Students' Attitudes Toward the Content of Science Courses," exhibited a Cronbach's Alpha coefficient of .64. The Cronbach's Alpha internal consistency coefficient for the entire scale was calculated as .86. According to Kalaycı (2010), the reliability coefficient interpretations based on the alpha coefficient are as follows:

0.00<α<0.40: The scale is not reliable.
0.40<α<0.60: The scale has low reliability.
0.60<α<0.80: The scale is fairly reliable.
0.80<α<1.00: The scale has high reliability.

Based on Kalaycı's (2010) criteria, the scale and its sub-factors are considered highly reliable.

The ethical process in the study was as follows:

- Ethics committee approval was obtained from Atatürk University Educational Sciences Ethics Committee (Date: 05.07.2022, Number: E-56785782-050.02.04-2200207614)
- Informed consent has been obtained from the participants.

Data Analysis

The SPSS 18 software package was used for data analysis. Before starting the analyses, assumptions such as the independence of the data, normality of distributions, and homogeneity of variances were tested to ensure the appropriateness of the tests. Once these assumptions were confirmed, parametric tests were conducted. To ascertain if there existed a notable distinction in the academic achievements of EG and CG students and their attitudes towards the science course, t-tests, one-way ANOVA, and ANCOVA were conducted. Additionally, the analysis of covariance method was used because it is a powerful statistical method that compares the mean scores by controlling one or more variables that are believed to be related to the dependent variable when examining the effect of the independent variable on the dependent variable in an experimental procedure In the analysis of covariance (ANCOVA), students' posttest scores on the Attitude Scale Toward Science Course were treated as the dependent variable, while the instructional method (STEM-integrated vs. traditional program-based) served as the independent variable. Pretest scores were included as a covariate to control for initial differences in students' attitudes toward science and to more accurately assess the effect of the instructional intervention. The ANCOVA was conducted in accordance with Büyüköztürk (2009), and the significance level was set at .05.

The homogeneity of variances test is explained in Table 2.

Table 2.

Test of Homogeneity of Variance

	Levene Statistic	df1	df2	p
FYTO (Pre-test)	3.56	1	38	.06
FYTO (Post-test)	0.54	1	38	.46
DSABT (Pre-test)	5.76	1	38	.07
DSABT(Post-test)	17.53	1	38	.30

*$p < .05$

Research Procedure

During the research process, the instructional models assigned to the experimental and control groups were implemented by the researcher across 6 instructional hours. Pretests and posttests were conducted to both groups on the same days, with a four-week instructional period between two assessments. The lessons were taught using the STEM-integrated instructional model in the experimental group, while the control group followed the program-based instructional model recommended by the MEB. In both groups, textbook-based activities were implemented in with the line instructional approaches.

Implementation of Program-Based Instruction

In the class designated as the CG, instruction was delivered in accordance with the sixth-grade science textbook provided by the MEB. The lessons were implemented over six instructional hours, strictly adhering to the curriculum and the instructional guidance outlined in the textbook. The instruction was supported with various visuals, videos, and slides. The activities in the textbook were carried out in paralle with the lesson content.

Implementation of STEM-Integrated Instruction (Implementation of the Scratch Program)

In the EG, instruction was delivered for six class hours using STEM-integrated instruction (Scratch program). Throughout the insructional process, the students engaged in researcher-designed STEM activities implemented via Scratch. The activities were completed individually and are detailed below:

Structure of the Heart

This activity aimed to teach students the anatomical components of the heart, one of the core structures of the circulatory system. A Scratch-based interactive game was developed by the researcher, in which students were instructed to drag and drop heart components displayed at the bottom of the screen into their correct positions on a heart diagram. When a correct match was made, the element locked into place, and a reinforcement sound (clapping) was played to provide immediate feedback.

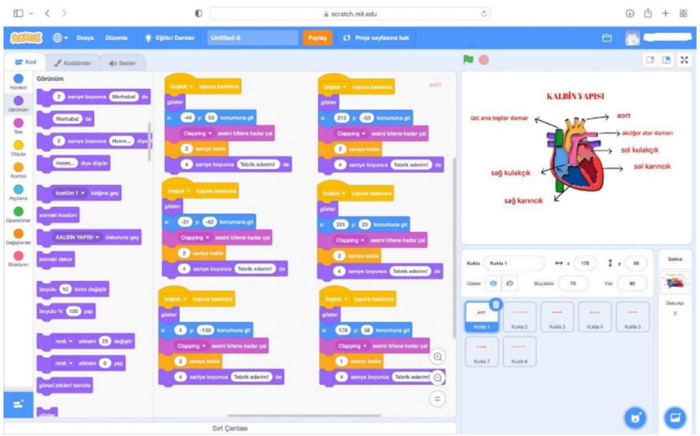

Figure 1.
Example of the Screen and Code Block for the Heart Structure Game

Quiz Competition

It was designed by the researcher to teach the achievements related to the circulatory system to the experimental group students through Scratch. An example of the Scratch screen and the code block for the quiz competition game are illustrated below.

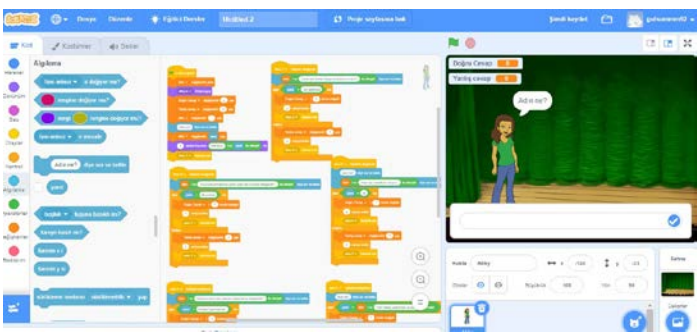

Figure 2.
Example of the Project Screen and Code Block for the Quiz Competition Game

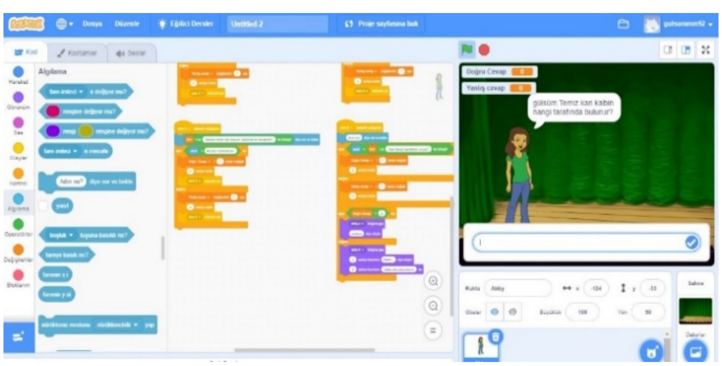

Figure 3.
Example of the Project Screen and Code Block for The Quiz Competition Game

At the start of the game, the students are prompted to enter. A sequence of multiple-choice questions is then presented. The program was coded to assign one point for each correct response and track incorrect answers. Upon completion, if a student answered at least two questions correctly, a congratulatory message ("Congratulations") appeared on the screen, providing positive reinforcement.

Systemic and Pulmonary Circulation

To facilitate learning among the experimental group students, a game focusing on systemic and pulmonary circulation was developed by the researcher using Scratch. An example of the Scratch screen and the code block for the systemic and pulmonary circulation game are illustrated below.

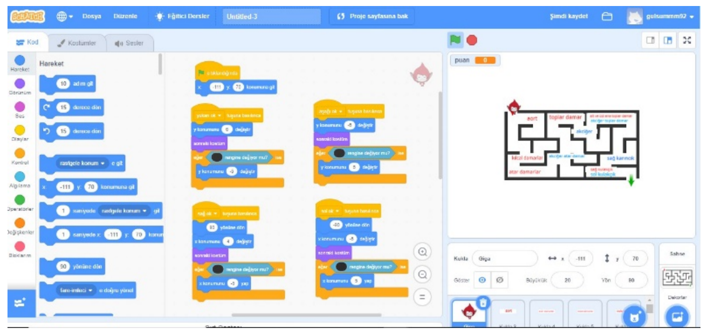

Figure 4.
Example of the Project Screen and Code Block for the Systemic and Pulmonary Circulation Game

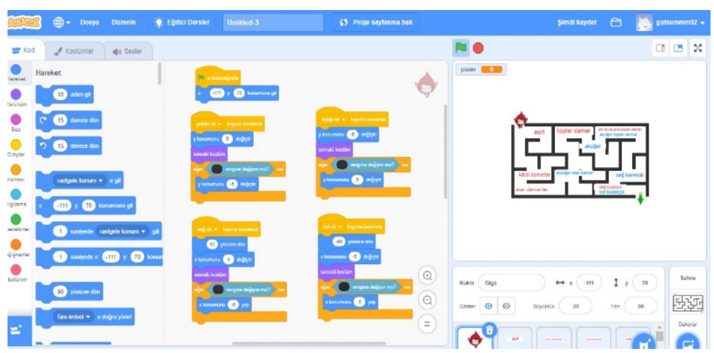

Figure 5.
Example of the Project Screen and Code Block for the Systemic and Pulmonary Circulation Game

A game was designed by drawing a diagram of the structures through which the blood passes in the systemic and pulmonary circulation on a maze. Command codes were written to make the sprite move right, left, up, and down in the maze. As the correct structures are encountered along the path of circulation, the score variable will increase by one point; if incorrect structures are encountered, the score will decrease by one point. The game concludes when the sprite reaches the designated endpoint, marked by a green arrow, at which point the message "Game Over" is displayed.

Results

This section presents the findings related to the main problem, derived from the data collection tools, are presented according to the sub-problems.

Findings Related to the Initial Sub-Problem

In the first sub-problem, the findings derived from both the pre-test and post-test of the CSAT, which was administered to determine the impact of STEM-integrated instruction and program-based instruction models on students' academic achievements in the circulatory system topic, are presented in tables. The pre-test application results are explained in Table 3.

Table 3.

Results of the Independent Groups t-Test of Data Obtained from the Pre-test of CSAT

Group	N	$\bar{X}$	sd	df	t	*p*
EG	20	30.60	15.14	38	0.79	.43
CG	20	27.40	9.90			

$^*p < .05$

When examining the analysis results given in Table 3, it is observed that there is no statistically significant difference in the academic achievements on the circulatory system topic between the group with integrated STEM activities ($\bar{X}$ =30.60) and the group with program-based instruction ($\bar{X}$ =27.40) before the instruction ($t_{(38)}$=0.79; $p > .05$). These findings demonstrate that, prior to the experimental intervention, the students in both groups had comparable achievement related to the circulatory system. Consequently, it can be asserted that the groups were equivalent in terms of their academic achievement.

To determine the impact of STEM-integrated instruction and program-based instruction on students' academic achievements in the circulatory system topic, the CSAT was re-administered as a post-test after the implementation of the methods. The post-test application results are shown in Table 4.

Table 4.

Results of the Independent Groups t-test of Data Obtained from the Post-test of CSAT

Group	N	$\bar{X}$	sd	df	t	*p*
EG	20	90.40	7.03	38	6.88	.00
CG	20	58.40	19.57			

$^*p< .05$

When examining the analysis results given in Table 4, it is evident that the academic achievements scores of the students in EG ($\bar{X}$ =90.40) statistically higher than those of students in the control group who received program-based instruction ($\bar{X}$ =58.40), [$t_{(38)}$= 6.881; p <.05; n^2=0.55]. This result indicates that 55% of the variance in students' academic achievement regarding the circulatory system can be explained by the instructional method employed during the lessons. According to Cohen (1988), this value represents a medium effect. Accordingly, the STEM activities implemented in the experimental group positively influenced the students' academic achievement in the the circulatory system.

Findings Related to the Second Sub-Issue

In the second sub-problem, the findings derived from the pre-test and post-test results of the ASSC, which was administered to determine the impact of lessons taught using STEM-integrated instruction and program-based instruction models on students' attitudes towards the science course, are presented in tables. As the data in the pre-test showed normal distribution, they were analyzed using the independent samples t-test. The pre-test scores results are explained in Table 5.

Table 5.

Results of the Independent Groups t-Test of Data Obtained from the Pre-test of ASSC

Group	N	$\bar{X}$	sd	df	t	*p*
EG	20	39.25	13.33	38	-2.11	.00
CG	20	47.05	9.75			

$^*p< .05$

When examining the analysis results given in Table 5, it is seenthat there is a statistically significant difference in the attitudes towards the science course between the group taught with STEM-integrated instruction ($\bar{X}$ =39.25) and the group taught with program-based instruction ($\bar{X}$ =47.05) before the intervention [$t_{(38)}$=-2.113; $p < .05$]. These findings indicate that, prior to the experimental intervention, the attitude levels of students in both groups toward science courses were not comparable. Therefore, it can be concluded that there was no equivalence between the groups in terms of their attitude levels.

To control for any pre-existing differences between the experimental and control groups at the outset of the study, and to ensure a more accurate evaluation of the intervention's effect, analysis of covariance (ANCOVA) was conducted. In this analysis, students' pretest scores were used as the covariate to determine whether the differences observed in the posttest scores could be attributed to the instructional treatment rather than initial disparities between the groups.

Table 6.
Results of the Covariance Analysis of Data Obtained from the Post-test of ASSC

Source of Variance	Sum of Squares	df	Mean Squares	F	*p*	η^2
Pre-test (total scores)	156.74	1	156.74	1.41	.24	.03
Groups	305.47	1	305.47	2.76	.10	.07
Error	4088.45	37	110.49			
Total	80106.00	40				
Adjusted Total	4763.60	39				

*$p < .05$

The analysis indicated that there is no statistically significant difference in the attitudes towards the science course between the students with STEM-integrated instruction and those with program-based instruction [$F_{(1-37)} = 305.472$, $p < .05$]. The effect size was calculated as $\eta^2 = 0.070$. These findings suggest that the STEM activities implemented did not result in a significant change in the experimental group students' attitudes toward science courses.

Discussion

In the study, the impact of the STEM-integrated learning model as part of the science curriculum on students' academic achievements in the circulatory system topic and their attitudes towards the science course was examined. According to the results obtained from the pre-intervention of CSAT, it was concluded that the pre-test knowledge levels of the groups were similar. Given that none of the students had previously studied the circulatory system topic, this finding was anticipated (Çakıcı, 2019; Gülbahar, 2023; İlkay, 2022; Sarıçam, 2019; Yalçınkaya, 2019; Yetişir, 2019). Following the implementation of the instructional interventions and the administration of the posttest, a statistically significant difference was observed between the groups ($p < .05$). This difference may be attributed to the nature of the STEM-integrated learning environment, in which the activities appealed to multiple cognitive domains and facilitated more meaningful engagement with the content. Such an environment may have enhanced students' understanding and reduced their perception of science as an obligatory subject.

Additionally, since it was determined that 55% of the increase in students' academic achievements in the circulatory system was accounted for by the implemented application, it can be said that integrating STEM activities into science lessons can make the teaching process more efficient. The results obtained regarding the increase in academic achievement in the circulatory system topic are consistent with the findings in the literature, which also indicate that integrating STEM activities has a positive impact on students' academic achievements (Alp, 2019; Gazibeyoğlu, 2018; Gökçe, 2019; Kapan, 2019; Kavak, 2019; Kurt, 2019; Taştan-Akdağ, 2017; Toprak, 2021; Zhang et al., 2022). Similarly, several studies have highlighted the positive impact of Scratch-based STEM applications on students' academic achievement (Kader, 2022; Karagöz, 2024; Keçeci, 2018; Koyuncu, 2022; Wen et al., 2023).

Although different teaching methods were used, several factors may explain the lack of a statistically significant difference in students' attitudes toward the science course. One possible reason is that students' prior negative experiences with science instruction may have shaped their perceptions and persisted throughout the intervention. Furthermore, the relatively short duration of the implementation period-limited to six class hours-may not have been sufficient to modify entrenched beliefs regarding science as a difficult and abstract subject. The abstract nature of the circulatory system topic, combined with the fact that students were encountering both the content and the instructional approach (i.e., fSTEM-integrated learning) for the first time, may also have existing literature is thoroughly examined, similar findings can be observed (Büyükkara, 2011; Doğan, 2019; Küçük, 2014; Neccar, 2019; Wendell & Rogers, 2013).

Conclusion and Recommendations

STEM-integrated instructional approaches have been found to significantly enhance academic achievement. In this study, students exposed to STEM-based learning demonstrated a more comprehensive understanding of the circulatory system and attained higher post-test scores. However, the integration of STEM activities did not result in a statistically significant improvement in students' attitudes toward science. Despite the improvement in academic performance, no statistically significant shift was observed in their perceptions of science courses. These findings underscore the effectiveness of STEM methodologies in facilitating conceptual learning and academic success, while highlighting the need for extended or more immersive interventions to influence students' attitudes toward science education.

To better understand students' attitudes towards science lessons, long-term and large-scale studies should be conducted. Teaching methods should incorporate activities and experiments that capture students' attention and engage them effectively. It is essential to create learning environments that foster active participation from students. Additionally, STEM activities should be developed, diversified, and implemented across various topics to integrate them into the curriculum; Where feasible, the establishment of dedicated STEM classrooms may support sustained implementation. Furthermore, activities and practices should be diversified by connecting them to real-life scenarios and other academic subjects to make learning more relevant and enriching.

This study is limited to a sample of 40 sixth-grade students from a single school and focuses exclusively on the circulatory system topic, where STEM activities were implemented. Additionally, the duration of the study (six weeks) may not have been sufficient to observe significant changes in students' attitudes.

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