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ORIGINAL RESEARCH PAPER

Exploring the Influence of STEAM Approaches on Ninth-Grade Kinematics Education

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ABSTRACT

This study investigates the effectiveness of the STEAM teaching method on ninth-grade students' understanding of kinematics concepts, including distance, displacement, and speed. The research employed a quasi-experimental design with pre-test and post-test assessments, involving control and experimental groups. The sample included 30 male ninth-grade students from regular schools in Qaen during the 2023-2024 academic years, selected through convenience sampling (15 in each group). A kinematics test developed by the researcher was used for data collection. Both groups took a pre-test, after which the experimental group received STEAM-based instruction over five 60-minute sessions, while the control group experienced traditional teaching. A post-test was administered afterward. Data analysis utilized the Kolmogorov-Smirnov test and analysis of covariance. Significant differences were found in the learning outcomes of the experimental group, confirming that the STEAM method is more effective than traditional methods ($P < 0.05$). The STEAM approach positively impacts student learning in kinematics, suggesting that educators should incorporate this innovative method into their teaching practices.

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INTRODUCTION

In today's rapidly evolving world, education is increasingly recognized as a cornerstone of both personal and societal development. The 21st century is characterized by swift technological advancements that introduce new challenges and complexities, fostering a sense of anxiety while simultaneously enhancing the demand for improved quality of life. This duality emphasizes the importance of timely and relevant education, compelling individuals to adapt and remain competent in a fast-paced environment. A key strategy for achieving this adaptability lies in enhancing the quality of educational systems.

Traditional educational methods often prioritize theoretical knowledge and rote memorization, inhibiting critical thinking and practical application. This limitation can diminish students' motivation, particularly in subjects perceived as difficult, such as physics. To counter these challenges, innovative educational approaches are essential. One promising framework is the STEAM approach, which integrates Science, Technology, Engineering, Arts, and Mathematics into a cohesive learning model. Rather than treating these disciplines in isolation, STEAM education promotes real-world applications, fostering connections among fields and encouraging creative problem-solving [1].

From an educational standpoint, the integration of STEAM disciplines facilitates a comprehensive approach to real-world problem-solving. Science provides methodologies for hypothesis testing and data analysis, while technology and engineering equip students with tools for innovation. Mathematics serves as a language for interpreting and representing information, promoting logical reasoning and critical thinking. The inclusion of the arts enhances creativity and interdisciplinary connections, encompassing fine arts, social sciences, and language. This synergy cultivates creativity and prepares students to tackle complex challenges with diverse solutions.

The debate surrounding the integration of these disciplines often hinges on whether they should be taught collectively or independently. Advocates for the STEAM model argue that incorporating the arts enriches learning experiences and fosters essential skills for addressing real-world issues [2]. The European Parliament has underscored the importance of arts education in nurturing creativity and providing innovative solutions. This integration enhances problem-solving capabilities and equips students to navigate the complexities of the modern world. STEAM education incorporates different modes of creative inquiry by blending arts and design, thereby fostering transdisciplinary approaches [3].

The expansion of STEAM education is evident in various countries, including Australia and the United States, where schools increasingly adopt this approach to enhance student outcomes and maintain global competitiveness [4]. Research has highlighted the positive impact of STEAM on elementary education, suggesting that these methods can significantly influence academic progress. Studies indicate that STEAM education enhances creativity, encourages innovative practices, and allows for experiential learning through trial and error.

Project-based and inquiry-based learning are central to the STEAM approach, transforming students from passive recipients of knowledge to active participants in their education. This shift enables students to engage with real-world challenges and develop critical and creative thinking skills. As they navigate these problems, students not only acquire new knowledge but also strengthen their teamwork and problem-solving abilities, contributing to their personal and social development [5].

Effective assessment systems aligned with STEAM principles can further stimulate student motivation. Integrating STEAM into curricula fosters key competencies such as cognitive abilities, collaboration, and innovation. Well-structured assessments empower students to identify knowledge gaps and take ownership of their learning, enhancing their intrinsic motivation and preparing them for future challenges [6]. Moreover, STEAM education emphasizes emotional engagement, providing timely feedback that fosters a sense of achievement and satisfaction. This positive reinforcement motivates students to continue learning and actively participate in their educational journey [7]. By equipping students with the skills and knowledge to tackle complex challenges, the STEAM approach contributes to creating a more just and sustainable future [8]. The intersection of STEAM with deep learning approaches emphasizes the human aspects of education, focusing on emotional experiences and student engagement [9]. This perspective fosters a connection between traditional culture and social responsibility, allowing students to see STEAM as more than just a set of tools. The importance of student interest in this type of education cannot be overstated [10].

Engagement in learning is closely linked to academic success, satisfaction, and retention. Creating interactive and personalized learning environments enhances student participation, necessitating varied instructional strategies and support from educators. Schools and policymakers must prioritize learning engagement, providing resources to improve the educational environment and stimulate student motivation [11].

STEAM projects harness active learning methods that promote student engagement, positioning learners as central actors in their educational experiences. This active involvement fosters scientific creativity and positive emotions in learning, enhancing attitudes towards education. Various methods, such as project-based and problem-based learning, contribute to developing practical knowledge and critical thinking skills.

Project-based learning, which starts with a question or challenge, allows students to engage deeply in their learning processes. If new challenges arise, problem-based learning techniques can be employed to navigate these obstacles. Both methods require a shift in classroom dynamics, necessitating new assessment systems and redefining teachers' roles.

Challenge-based learning, a specific active method, encourages students to explore broad questions and seek effective solutions. This approach enhances personal skills such as teamwork, negotiation, and leadership, all crucial components of emotional intelligence.

The integration of STEAM into various disciplines, including law and literature, presents challenges, particularly in fields heavily reliant on scientific principles. However, foundational sciences like mathematics and physics are integral to engineering, making them more compatible with STEAM methods. Research indicates that student interest in mathematics declines at higher education levels, impacting performance in related subjects like physics [12,13]. STEAM education aims to enhance students' interest and comprehension of scientific technology, fostering literacy in STEAM fields and equipping them with the skills to tackle real-world challenges [14]. This approach is implemented through two primary elements: 1) a curriculum rooted in scientific technology, and 2) the development of problem-solving abilities applicable to real-life situations. Insufficient mathematical skills can hinder success in physics courses, highlighting the need for innovative teaching methods.

Kinematics, a key area of physics, requires a blend of theoretical and practical understanding. Many students struggle with fundamental concepts, often due to misconceptions stemming from traditional teaching methods. Employing the STEAM approach in kinematics instruction can enhance students' comprehension and critical thinking skills.

Problem Statement

In recent years, the integration of STEAM (Science, Technology, Engineering, Arts, and Mathematics) education has gained traction as a means to enhance student engagement and understanding across various subjects. However, despite its growing popularity, empirical evidence regarding the specific impact of STEAM teaching strategies on students' comprehension of complex scientific concepts—particularly in the field of kinematics—remains limited. Ninth-grade students, who are typically transitioning into more advanced scientific curricula, often struggle with abstract concepts such as motion, velocity, and acceleration. This gap in understanding can significantly hinder their overall performance in physics and related disciplines.

Given the importance of a solid foundation in kinematics for future studies in science and engineering, it is crucial to explore how STEAM approaches can effectively facilitate learning in this area. This study aims to investigate the influence of STEAM teaching strategies on ninth-grade students' kinematics education, assessing both cognitive and affective outcomes of such instructional methods. By identifying best practices and potential challenges, this research seeks to contribute to the development of more effective teaching frameworks that enhance student learning and interest in physics.

Furthermore, this research aims to develop a curriculum that integrates STEAM concepts to bolster students' understanding of kinematics. Grounded in theories of participatory learning and constructivism, the study emphasizes the importance of active participation and student-centered learning in achieving academic progress [15]. By focusing on these principles, the curriculum aspires to foster deeper engagement and understanding, thereby preparing students for the complexities of the modern world.

Method

This research is a quasi-experimental study that employs a pre-test and post-test design with a control group. It falls under the category of applied research. The statistical population of this study includes all male ninth-grade students in the first secondary level of Qaen city of Iran during the academic year 2022-2023. Random sampling was used in this study. For blended learning programs like STEAM, small class sizes were chosen to facilitate interaction between teachers and students. Typically, a small class should not exceed 25 students [16]. Using a convenience sampling method, 30 students were selected and randomly assigned to two groups: a control group and an experimental group (15 students in the control group and 15 in the experimental group). The study population consisted of male and female students aged 14 to 15 years.

To assess the students' understanding of kinematics concepts related to the ninth-grade physics curriculum, a multiple-choice test was designed based on the educational content of the ninth-grade physics textbook. The educational objectives of the questions were aligned with the six levels of the cognitive domain and comprehension of the material. Based on the educational content, 100 questions were developed by the researcher and 13 experienced teachers. After review by experts and experienced teachers, 8 questions were extracted as the final questions.

The questions were then matched to a two-dimensional table of specifications, and a corresponding test form was created that was equivalent in measuring the six levels of the cognitive domain and all relevant characteristics, including difficulty level, discrimination, number of questions, etc. To evaluate content validity, these tests were presented to 15 experienced teachers and physics professors to confirm their alignment with the educational objectives and the content of the subject under study. The reliability of the test was assessed using Cronbach's alpha formula, which yielded a

Cronbach's alpha of 0.84, indicating statistically significant reliability and demonstrating that the test has adequate reliability.

After selecting the experimental and control groups, the test was administered to both groups. Following the pre-test, the independent variable (the use of STEAM-based teaching) was implemented in five 60-minute sessions for the experimental group. The control group was not exposed to the independent variable and was taught using traditional teaching methods. In the traditional teaching method, the teacher presents the content of the textbook unidirectionally, and students act merely as receivers of information.

Session Implementation and Execution

After the pre-test, the experimental group underwent five sessions of instruction using the STEAM teaching method. During these five sessions, students were initially challenged with clips and animations related to distance, displacement, speed, and velocity, building on their prior knowledge of kinematics. One session was dedicated to explaining the physical concepts of kinematics .

In another session, theoretical and mathematical aspects of the topic were discussed. Subsequently, students were divided into three groups of four and one group of three, where they used available materials to construct handmade vehicles. Each group then designed specific paths to calculate the average speed and velocity of their handmade devices. To visualize the paths of the vehicles and enable the drawing of displacement vectors, students coated the tires of their vehicles with paint to mark the distance traveled and the displacement of each vehicle.

Through the mathematical calculations related to the movement of the vehicles and the geometry of their paths, enhanced by the colored lines created by the paint on the tires, their mathematical skills were also strengthened. Throughout all sessions, efforts were made to implement the STEAM approach in the classroom by encouraging student participation and utilizing their creativity and artistic abilities.

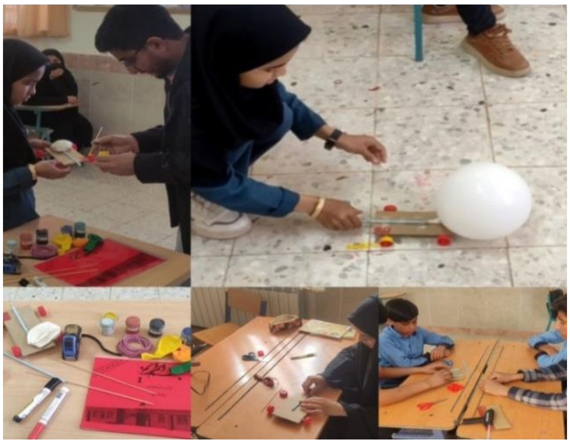

Figure 1. Implementation of Kinematics Teaching with the STEAM Approach

The control group, on the other hand, received instruction on kinematics concepts through traditional teaching methods, which included lectures and problem-solving, where students acted merely as receivers of information. After the intervention, a post-test on kinematics concepts was administered to both the experimental and control groups simultaneously and under the same conditions. Finally, the collected data were analyzed at both descriptive and inferential levels using SPSS software version 25.

Findings

In this study, a sample of 15 individuals was randomly selected for both the experimental and control groups. The findings are presented in two sections: descriptive and inferential statistics. The normality of data distribution was assessed using the Kolmogorov-Smirnov test along with skewness and kurtosis coefficients.

The pre-test and post-test scores for kinematics concepts and their subcomponents in the experimental group are described in Table 1. In the experimental group, the pre-test scores for kinematics concepts had a mean of 5.98 and a standard deviation of 1.15, showing positive skewness and kurtosis. In the post-test phase, the scores had a mean of 7.78 and a standard deviation of 1.23, with positive skewness and negative kurtosis. The skewness coefficients ranged from -3 to 3, and the kurtosis coefficients ranged from -10 to 10. Therefore, the normality of the data is confirmed. The following table summarizes the performance of the experimental group in understanding kinematics concepts and subscales related to distance, displacement, and speed before and after the intervention.

Table 1. Description of Kinematics Concepts Scores and Their Subcomponents in the Experimental Group

Subscale	Phase	Mean	Standard Deviation	variance	skewness	kurtosis	P-Value
kinematics concepts	Pre-test	5.98	1.15	1.33	0.14	0.23	0.14
	Post-test	7.78	1.23	1.52	0.07	-0.31	0.19
Distance and displacement	Pre-test	3.06	1.22	1.49	0.12	-1.03	0.21
	Post-test	4.66	1.17	1.38	-0.15	-1.47	0.15
speed	Pre-test	2.46	1.06	1.12	0.93	1.15	0.26
	Post-test	4.93	0.79	0.63	-0.84	1.45	0.31

A significant increase in understanding of Kinematics Concepts was observed from the pre-test to the post-test. The P-values suggest that the distributions of the scores do not significantly differ from normal, which supports the reliability of these findings.

The pre-test and post-test scores for Kinematics Concepts and their subcomponents in the control group are described in Table 2. In the control group, the pre-test scores for Kinematics Concepts had a mean of 5.85 and a standard deviation of 1.17, exhibiting negative skewness and positive kurtosis. In the post-test phase, these scores had a mean of 5.98 and a standard deviation of 0.98, with both skewness and kurtosis being positive. Therefore, it can be concluded that the data in the control group are normally distributed.

Table 2. Description of Kinematics Concepts Scores and Their Subcomponents in the Control Group

Subscale	Phase	Mean	Standard Deviation	variance	skewness	kurtosis	P-Value
kinematics concepts	Pre-test	5.85	1.17	1.39	-0.19	2.41	0.24
	Post-test	5.98	0.98	0.96	0.62	0.04	0.29
Distance and displacement	Pre-test	2.93	1.16	1.35	0.14	-1.17	0.28
	Post-test	2.93	1.22	1.46	0.41	-0.87	0.32
speed	Pre-test	2.46	1.12	1.26	-0.07	-1.32	0.14
	Post-test	2.60	1.24	1.54	0.12	-0.65	0.19

The P-values indicate that the distributions of the scores do not significantly differ from normal, which confirms the reliability of the findings. This suggests that the results obtained from the control group can be considered stable and valid for further analysis.

After confirming the normality of the data distribution, a T-test for dependent and independent samples was used to analyze the inferential data, comparing the mean scores of the STEAM method in the experimental group with the traditional teaching method in the control group. Additionally, ANCOVA was employed for significance analysis .

To compare the pre-test scores of Kinematics Concepts among ninth-grade students in both the experimental and control groups, the groups were matched. An independent T-test was utilized to assess the equivalence of the two groups at baseline (pre-test). The results of the statistical analysis comparing the mean pre-test scores for Kinematics Concepts in the experimental and control groups are presented in Table 3. The mean pre-test score for the experimental group was 5.98, while for the control group, it was 5.85.

Table 3. Results of Independent T-test for Comparing Mean Pre-test Scores of Kinematics Concepts in Experimental and Control Groups

Group	N	Mean	Standard Deviation	T	Significance	Degrees of Freedom
Experimental	15	5.98	1.15	-0.31	0.75	28
Control	15	5.85	1.17			

Using Levene's test, the homogeneity of variances between the control and experimental groups was examined. The results indicate that the Kinematics Concepts are comparable between the two groups. According to Table 4 and the reported significance level ($p = 0.97$, which is greater than 0.05), no significant difference was observed in the mean pre-test scores between the two groups. The effect size was greater than 0.33, indicating practical significance, while the effect size ($d = 0.11$) was large but not substantial.

Table 4. Results of Levene's Test for Homogeneity of Variances for Pre-test Scores of the Two Groups

Levene's Test	F	Significance
Pre-test Kinematics Concepts	0.001	0.97

No significant difference was found in the pre-test scores for Kinematics Concepts between the experimental and control groups. The analysis confirmed the homogeneity of variances, supporting the validity of the comparisons made.

To compare the learning of Kinematics Concepts among students at the pre-test and post-test stages, a paired T-test was conducted separately for each group. The results of the statistical analysis comparing the mean scores of the pre-test and post-test for the experimental and control groups are presented in Table 5. The results indicate that the mean scores for Kinematics Concepts increased for students in the experimental group. This increase in mean was statistically significant with a T-value of -23.05 and a significance level of ($p = 0.001$). Conversely, the increase in the control group was not statistically significant, with a T-value of -1.04 and a significance level of ($p = 0.31$). The effect size in the experimental group was large and significant ($d = 1.51$), while in the control group it was not significant ($d = 0.09$).

Table 5. Results of Dependent T-test for Comparing Mean Pre-test and Post-test Scores of Kinematics Concepts in Experimental and Control Groups

Variable	Group	**Phase**	N	Mean	Standard Deviation	T	Significance	Degrees of Freedom
Kinematics Concepts	**Experimental**	Pre-test	15	5.98	1.15	-23.05	0.001	14
		Post-test	15	7.78	1.23			
	Control	Pre-test	15	5.85	1.17	-1.04	0.31	14
		Post-test	15	5.98	0.98			

To compare the mean differences in pre-test and post-test scores of Kinematics Concepts between the experimental and control groups, an independent T-test was used. As shown in Table 6, the mean difference in scores between the pre-test and post-test for the experimental group was -1.80, while for the control group, it was -0.13.

The results of the independent T-test for comparing the mean differences in pre-test and post-test scores of Kinematics Concepts between the experimental and control groups are summarized in Table 6. The analysis shows a significant difference in the mean scores, with a T-value of 11.14 and a significance level of ($p = 0.001$), which is less than 0.05. The effect size was large ($d = 4.28$), indicating a substantial impact of the STEAM intervention on the learning outcomes.

Table 6. Results of Independent T-test for Mean Differences in Pre-test and Post-test Scores of Kinematics Concepts

Group	**N**	**Mean**	**Standard Deviation**	**T**	**Significance**	**Degrees of Freedom**
Experimental	15	-1.80	0.30	11.14	0.001	28
Control	15	-0.13	0.49			

According to Table 7, the results of Levene's test confirmed the homogeneity of variances for the differences in pre-test and post-test scores of Kinematics Concepts between the two groups. The F-value was 0.05, with a significance level of 0.81, indicating that the variances are equal.

Table 7. Results of Levene's Test for Homogeneity of Variances for Differences in Pre-test and Post-test Scores of Kinematics Concepts

Levene's Test	**F**	**Significance**
Differences in Scores	0.05	0.81

The STEAM teaching method demonstrated a significant positive effect on students' understanding of Kinematics Concepts. The large effect size indicates that the intervention had a strong and meaningful impact on learning outcomes. The homogeneity of variances supports the validity of the findings, confirming that the groups were comparable at baseline.

Discussion and Conclusion

The STEAM approach, emphasizing the interconnection between Science, Technology, Engineering, Arts, and Mathematics, enables students to understand scientific concepts through projects and hands-on experiences. This approach can help students develop a deeper understanding of kinematics concepts by utilizing creative thinking and problem-solving, ultimately leading to more effective and lasting learning.

In this study, an independent T-test was employed to compare the mean differences in pre-test and post-test scores of kinematics concepts between the experimental and control groups. The results of the analysis of variance indicate a significant difference in the effectiveness of the STEAM teaching method compared to traditional teaching methods on learning kinematics concepts ($F = 0.05$ and $P < 0.05$). The mean score of the experimental group (7.78) was significantly higher than that of the control group (5.98). Additionally, the mean score of the experimental group in the post-test (7.78) was significantly higher than its pre-test mean (5.98). The mean kinematics concepts score in the experimental group increased from pre-test to post-test, and this increase was statistically significant. In the control group, the mean kinematics concepts score also increased in the post-test, but this increase was not statistically significant. The effect size in the experimental group was large and meaningful. The calculated effect size in this study demonstrated that the application of the STEAM teaching method had a strong and valuable intervention effect on learning kinematics concepts.

These results align with previous studies by Ozkan and Emdo Topçakal (2020)[17], Saleh and Abdullah (2020)[18], and Putri et al. (2020)[19], which found the implementation of the STEAM teaching method beneficial for enhancing student learning. Overall, the findings of the present study suggest that the implementation of the STEAM method in teaching kinematics can help address existing challenges in this subject area and provide students with the opportunity to learn scientific concepts in a conceptual and practical manner.

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