International Journal of Education and Practice
2025 Vol. 13, No. 2, pp. 637-652
ISSN(e): 2310-3868
ISSN(p): 2311-6897
DOI: 10.18488/61.v13i2.4121

Adoption of the steam approach in grade school mathematics instruction: Insights and challenges from math teachers' perspectives

Awad Faek Altarawneh

Department of Teaching and Curriculum, Faculty of Educational Sciences the Hashemite University, Zarqa 13133, Jordan.
Email: a.altarawneh@hu.edu.jo

Article History
Received: 2 September 2024
Revised: 30 January 2025
Accepted: 17 February 2025
Published: 5 March 2025

Keywords
Artificial intelligence
challenges
Mathematics teachers
STEAM approach.

ABSTRACT

The current research explores how far the STEAM approach has been adopted in teaching mathematics in Jordan based on math teachers' perspectives. Moreover, it examines the challenges that hinder the implementation of the STEAM model. A mixed-method research design involving descriptive-analytical methods and semi-structured interviews was adopted. The primary study tool is a specially designed questionnaire with four main axes. The questionnaire was randomly distributed to a selected sample of 304 math teachers working in government schools in Amman. The results depicted a moderate adoption of the STEAM approach in mathematics education. No statistically significant differences ($p>0.05$) were observed in the variables of gender or grade level taught. However, statistically significant differences ($p>0.05$) were found for the variables of training courses and teaching experience with those who had received specialized training courses in STEAM and those with five or more years of teaching experience demonstrating higher levels of implementation. Mathematics teachers faced challenges in using Artificial Intelligence (AI) and incorporating it into the teaching process when instructing students of the upper high school grades (ninth and tenth grades). Different challenges were classified into AI-related, teacher-related, student-related, curriculum and content-related and school and classroom environment-related obstacles.

Contribution/Originality: This article offers insightful information about the extent and efficacy of integrating this interdisciplinary approach into the curriculum by analyzing the degree of STEAM adoption in mathematics education. It provides original insight into the challenges and obstacles of integrating STEAM and Artificial Intelligence (AI) into mathematics teaching.

1. INTRODUCTION

Numerous aspects of human existence have undergone substantial metamorphosis in the contemporary era of rapid scientific and technological progress. The educational sphere has not remained impervious to these transformations with a paradigm shift towards learner-centric pedagogies wherein teachers assume facilitative roles (Abdel Aziz, 2005).

The STEAM model is an innovative and pivotal approach. STEAM stands for Science, Technology, Engineering, Arts, and Mathematics among the attempts to find the most efficacious teaching strategies. The major objective of using this model is to assist learners with adopting critical thinking skills that enable them to tackle problems in multifaceted ways and train them in various practical competencies that will allow them to compete in our dynamic (Suryani, Kun, & Haryanto, 2023). It is necessary for those who set educational curricula to concentrate on the practical application of scientific principles to reach this goal. Naturally, these principles must be grounded in knowledge and students must be trained to apply their skills across multiple contexts (Al-Ahmedi, 2019).

Research has demonstrated that learners facing new concepts do better when the information is presented through visual stimuli. They retain the information more readily when explained in images, graphics, and diagrams. Students using traditional rote memorization techniques to assimilate knowledge are less stimulated by the learning process (Aldosari, 2015). The STEAM model provides stimuli promoting brain function in learners and encouraging them to engage with the material and their environment. This circumstance contributes greatly to their attainment of learning objectives (Asquol & Abu Odeh, 2016). Hence, it captivates learners' attention, facilitates comprehension of educational content, and elucidates complex meanings and ideas. Furthermore, our mnemonic capacity for visual information appears to surpass that for verbal information (Aldulaymi & Al-Owaidi, 2021).

Contemporary educational paradigms underscore the imperative of updating pedagogical strategies to encompass all facets proving advantageous to learners. This adaptive approach equips them with the requisite skills to navigate the exigencies of the current century and traverse the ever-evolving landscape of knowledge and technological innovation (Hynes, Costin, & Richardson, 2023). A fundamental aspect of this transformation involves transitioning learners from passive recipients of knowledge to active participants and creators in the learning process (Alkhawaldeh, 2017).

Within this context, theoretical literature and extant research highlight the pivotal role of teachers in designing, implementing, and evaluating the teaching process, particularly regarding the integration of the STEAM approach. Evidently, the interactive relationship between teachers and students has become essential if students are to reach their full potential. For this study, teacher-student interaction is critical to achieving excellence in mathematics instruction (Al-Ma'afa, 2020). Teachers can achieve excellence by supporting learners while striving to cultivate their critical cognitive skills, understanding and explaining natural and scientific phenomena, and developing their analytical skills. Specialized training programs can be provided to nurture innovative thinking in every aspect of the educational process (Al-Mohammadi, 2018).

In the digital era, every aspect of our lives has changed and has been changing. Thus, students must master the necessary skills. The current research evaluates how AI and STEAM education can be integrated into the learning process to cultivate creativity, critical thinking, problem-solving, and technical skills. Even though AI and STEAM both offer undeniable advantages, numerous obstacles must be overcome to successfully incorporate them into the education system with their potential fully realized (Al-Muhaysin & Khaja, 2015; Celik, 2023).

Several prerequisites must be met before the STEAM can be successfully implemented. Firstly, teachers must acquire many professional and educational competencies (Al-Qahtani & Al-Kahlan, 2017). Secondly, curricula must be amended to align with the STEAM approach; otherwise, the full benefits cannot be reaped (Al-Qathami, 2016). STEAM may assist in developing a generation of students with competent and adaptable knowledge and abilities after achieving these goals. Al-Muhaysin and Khaja (2015); Al-Qathami (2016) and Alsanania (2017) posit that the prerequisites for the successful implementation of the STEAM model in the teaching of mathematics can be categorized as follows:

1. Planning: When preparing lessons, teachers must use engineering design principles to structure mathematical problem-solving strategies. Workshops and group activities should be organised regularly, and students should be urged to deduce mathematical concepts and skills. Various subjects within the STEAM model should be integrated into math topics promoting multifaceted thinking. Thus, students are stimulated to seek information from various sources, using STEAM disciplines to address societal, vocational, and economic challenges. Students establish their conclusions when using their research skills to

test already proven solutions. This step reinforces their understanding of the concept and boosts their confidence in their capabilities.

2. Implementation: Teachers should allow students to observe and conduct multiple skills, thus fostering critical and creative thinking capabilities. Educational objectives are attained through hands-on activities and digital simulations based on the integration of STEAM principles.
3. Evaluation: Teachers must assess students' progress towards achieving educational objectives through various diagnostic, preventive and remedial methods. Assessments should encompass cognitive, skill-based, and emotional aspects. Under this framework, evaluation should be a collaborative endeavor involving other stakeholders in addition to the students, such as math instructors, colleagues, and parents. Rigorous scientific foundations, including validity, reliability, and objectivity, underpin the evaluation process where diverse tools like tests, interviews, observations and achievement files are employed.

The present investigation focuses on determining how mathematics teachers in public institutions in Amman, the capital of Jordan based on their perceptions; implement the STEAM methodology in their pedagogical practices. It also explores if any statistically significant variations exist between the participants regarding the extent of STEAM approach implementation in mathematics instruction for the study variables (gender, duration of teaching experience, professional development courses, and grade levels taught). The researcher also aims to identify the obstacles encountered by the same teachers' perspectives when they attempt to implement the STEAM approach in Amman's public schools.

This investigation addresses the vital topic of integrating the STEAM methodology into mathematics teaching practices in Jordan. The findings can guide educational leaders in cultivating an optimal learning environment conducive to implement the STEAM approach and provide a valuable resource for scholars searching deeper into this domain. Several studies have already proven that the STEAM approach is an effective method of instruction. Aqel and Azam (2022) asserted that students enthusiastically received a STEAM-based science unit. Al-Umairi (2022) reported that a STEAM-oriented program helped students cultivate their mathematical problem-solving skills and critical thinking capacities. Furthermore, Kuware' (2017) found the STEAM approach to be highly effective in giving math learners an increased comprehension of new concepts and fostering creative thinking skills.

The researcher was prompted to scrutinize further the implementation of the 'Unit Project' in Jordanian mathematics textbooks because the STEAM approach has gained substantial popularity. The researcher wanted to measure how well teachers implemented the project while integrating the STEAM methodology and identifying the challenges encountered during its execution. The researcher formulated the following research questions (RQ) based on the promising indications of the STEAM approach:

RQ (1): Based on their perception, to what extent do mathematics teachers in public institutions in Amman, the capital, implement the STEAM methodology in their pedagogical practices?

RQ (2): Do the mean scores of study participants reveal any statistically significant variations (α=0.05) regarding the extent of STEAM approach implementation by mathematics teachers in Amman's public schools for the study variables (gender, duration of teaching experience, professional development courses, and grade levels)?

RQ (3): What obstacles do mathematics teachers face during the implementation of the STEAM approach in Amman's public educational institutions, according to their perspectives?

2. LITERATURE REVIEW

2.1 STEAM Approach

A substantial corpus of educational research has extolled the merits of integrating the STEAM approach into mathematics instruction, underscoring its efficacy. Concurrently, these investigations have elucidated various obstacles teachers confront while implementing this pedagogical framework.

Kuware' (2017) defined STEAM as an interdisciplinary pedagogical framework integrating scientific concepts with natural phenomena. It enables learners to apply principles from science, technology, engineering, mathematics, and the arts within contexts, promoting robust school-community connections, facilitating the acquisition of scientific literacy and boosting global economic competitiveness.

AI-based fundamental mathematics teaching adapts to and prioritizes student personality development under contemporary educational conditions (Demetriou, Spanoudis, Makris, Golino, & Kazi, 2021). In mathematics education, animation of mathematical figures and representations created with appropriate software is employed to boost students' imagination and self-learning abilities (Voskoglou & Salem, 2020). Computer-based learning systems are replacing teachers, trainees, or tools, apart from facilitating policy decisions as AI technology becomes increasingly more involved in educational settings (Celik, 2023).

Anizat (2022) defines challenges as "the obstacles or impediments faced by teachers that hinder the attainment of the subject's intended learning outcomes." In this study, challenges are described as the obstacles and impediments mathematics teachers face in technical, material, administrative, and environmental aspects. These challenges impede the implementation of the STEAM approach in achieving desired instructional objectives as measured by the instrument employed in this study.

Aldulaymi and Al-Owaidi (2021) assessed STEM application in physics education in Iraq with a descriptive survey approach involving 108 teachers from 23 schools in Anbar Province. A 30-item questionnaire across planning, implementation, and evaluation domains was used in the study and revealed moderate STEM integration levels. The evaluation domain emerged as predominant followed by planning and implementation. No significant variations were discerned based on gender, qualifications or experience.

Manazir and Al-Hanaki (2021) explored obstacles to STEM integration from the female teachers' perspective in middle and high schools in Saudi Arabia. The analytical descriptive study involving 105 respondents identified moderate barriers for teacher, student, environmental, and content-related domains. Key challenges encompassed limited teacher knowledge, inadequate student practical skills, overcrowded classrooms, insufficient resources, and curriculum misalignment.

Saleh, Abu, and Abdu (2019) researched STEM's efficacy in enhancing mathematics achievement among Palestinian tenth-grade students. Fifty participants were divided into a control and an experimental group. The results demonstrated significantly higher ($p<0.05$) post-test achievement in the STEM-instructed cohort. Furthermore, Al-Mohammadi (2018) examined STEAM's impact on problem-solving abilities among female secondary students in Saudi Arabia. The design was a quasi-experimental, single group with 30 participants. The study depicted STEAM's effectiveness in cultivating problem-solving skills.

James (2017) evaluated STEAM's impact on seventh-grade science and mathematics achievement in Tennessee, USA. The experimental study involved 631 students, unexpectedly revealing superior performance in conventionally taught groups than STEAM-instructed cohorts. Lou, Tsai, Tseng, and Shih (2014) studied the effects of problem-based learning on the attitudes of 40 first-year Taiwanese high school students towards STEM integration. The students participated in a solar-powered car lift design project. The findings demonstrated positive outcomes in learning attitudes, career identification, task completion, interdisciplinary comprehension, and skill application. Al-Qahtani and Al-Kahlan (2017) identified obstacles to STEM implementation in Saudi Arabian middle school mathematics instruction. The descriptive study encompassing 103 teachers and supervisors in the Aseer region, reported student-related challenges as the most significant followed by content, teacher, and environmental barriers. Olivarez (2012) also investigated a STEAM-based program's impact on academic achievement among 176 eighth-grade students in South Texas using a quasi-experimental study. The study's results revealed that those in groups where STEAM instruction was employed demonstrated superior performance in mathematics, science and reading.

2.2. AI and STEAM

We have recently witnessed more prevalent conversational generative artificial intelligence (Gen AI) use in society and numerous industries. Technologies such as Open AI's Chat GPT can perform as well or often better than humans and are thus rapidly gaining in popularity. However, major pitfalls to using Gen AI production exist in its current form. When used as a learning artefact, it may inhibit deeper learning. If students rely excessively on Gen AI, they may only achieve superficial learning or even not learn at all (Chng, Tan, & Tan, 2023). Gen AI output also poses a high risk of plagiarism. It may also contain disinformation or biases.

Artificial intelligence can be used in teaching mathematics as one of the integrated applications in STEAM. The integration of AI and STEAM education integration is now pivotal in the digital era and it is used to prepare students for an ever-changing world. The AI and STEAM education offers a potent framework for developing technical skills, creativity, critical thinking, and problem-solving (Ayanwale, Adelana, & Odufuwa, 2024). We examine the advantages and challenges of incorporating AI and STEAM education into the classroom and discuss how this integration can completely transform the educational system in the current article.

When students adopt the use of AI in supervised collaboration, they can achieve a higher level of learning through numerous active and mutual interactions. Vygotsky (1896-1934) asserted that individuals primarily learn in social and cultural settings (Schreiber & Valle, 2013). Piaget (1896-1980), a developmental psychologist who inspired radical constructivism, opined that people build their knowledge through "the interaction of their experiences and ideas." Vygotsky advocates for collaboration between peers to achieve optimum learning whereas Piaget encourages student–AI collaborative relationships. Shared learning objectives, equitable partnerships, maximum peer contacts, personal accountability and constructive interdependence are some characteristics of collaborative learning on both sides (Manazir & Al-Hanaki, 2021).

Numerous studies have addressed the benefits of using Gen AI tools to improve the experience of those learning programming. Yilmaz and Yilmaz (2023) conducted a case study to reveal the opinions of university students concerning the Gen AI tool. Over eight weeks, the students were asked to complete programming assignments using Gen AI. Subsequently, they were surveyed about their experiences. Regarding the tool's advantages, they listed its efficacy in helping develop critical thinking skills, offering debugging support, and quick responses. On the other hand, they reported that Gen AI urged them to be lazy, sometimes generated incorrect answers, and the programming environment was inadequate.

According to several studies, if students want to survive in the digital age when they reach the workforce, it is now essential that AI and the STEAM framework be integrated into the curriculum (Ayanwale, 2023). When combined effectively, AI and STEAM education can substantially contribute to developing students' technical skills, creativity, critical thinking, and problem-solving. The researcher examines the benefits and challenges of incorporating AI and STEAM education into the classroom and discusses how these tools can feasibly transform the education system in this study.

The researcher undertook a comprehensive review of the existing literature addressing the implementation of STEAM or STEM approaches in educational contexts to gain a comprehensive picture of the topic. Anizat (2022) examined the obstacles to STEM integration in mathematics instruction, working in the government schools of the Ajloun Governorate in Jordan. The study adopted a descriptive survey methodology comprising a sample of 130 teachers. According to the findings, most were related to students, although several had environmental and content-specific issues. No gender-based disparities were observed even though higher educational qualifications correlated with perceived challenges.

At the classroom level, AI applications can be effectively integrated to improve instruction by adapting learning materials and organizing activities into the most beneficial order. These applications can also prove useful in offering feedback to individual students, helping them advance. Thus, AI is a handy tool for identifying resources and pedagogical approaches that suit specific students' needs, foreseeing possible outcomes, and guiding them on the right path to achieving optimum results. Within the school environment, AI applications can benefit both management and the system, for instance, by helping reduce dropout. Students can be taught new skills that enable them to complete their education rather than drop out of school by predicting impending problems and providing assistance at the right time (Molefi & Ayanwale, 2023).

3. METHODOLOGY

3.1. Research Design

The researcher used a mixed-methods research design that involved descriptive-analytical methods with both qualitative and quantitative approaches while conducting this study. Initially, a descriptive survey methodology provided core quantitative data to measure the extent of STEAM approach implementation in mathematics instruction in government schools in Amman regarding several variables. Subsequently, the researcher conducted semi-structured interviews with 25 math teachers. The interviews yielded qualitative data that revealed the challenges the teachers encountered when they endeavored to implement the STEAM approach.

3.2. Research Population

This investigation focuses on implementing the STEAM approach by mathematics teachers in government schools in all educational directorates in Jordan's capital city, Amman during the academic year 2023/2024. The study population comprises mathematics teachers in public schools across all educational directorates of Amman. The statistics from the Ministry of Education for the academic year 2023/2024 suggest that the total number of mathematics teachers in government schools in Amman was 2,873, with 1,237 males and 1,636 females. The researcher selected a sample of 304 math teachers (134 males and 170 females), representing approximately 11% of the total study population using simple random sampling techniques. Table 1 depicts the detailed information of the sample.

Table 1. Frequencies and percentages by study variables.

Variables	Levels of variable	Frequencies	Percentage
Gender	Male	134	44.1
	Female	170	55.9
Teaching experience	Less than a year	25	8.2
	Between 1 and 5 years	46	15.1
	More than 5 years	233	76.6
Training courses	Attended	170	55.9
	Have not attended	134	43.1
Grade levels	4-6	201	66%
	7-10	103	34%
	Total	304	100.0

3.3. Research Instrument

The researcher developed a questionnaire based on relevant prior studies to serve as the primary research instrument. The questionnaire was designed to meet the specific purpose of the current research based on works by Al-Umairi (2022); Aldulaymi and Al-Owaidi (2021) and Aqel and Azam (2022). Initially, the instrument comprised 49 items distributed across the following three domains: planning, implementation, and evaluation representing the educational competencies requisite for STEAM-based instruction.

The questionnaire encompassed a five-point Likert scale assigning each item a value from 1 to 5 (1= never , 2= rarely, 3= sometimes, 4= often, and 5= always). Subsequently, it was digitized and disseminated electronically to the study sample of teachers in public schools during the second semester of the 2023/2024 academic year. The researcher used communication channels of the educational directorates in Amman to facilitate distribution. The electronic survey was accessible for three weeks, ensuring complete data collection from the entire study sample and avoiding non-responses. Once all the data had been collected, the scores were calculated. Statistical analysis was conducted using the following equation to determine the means of individual items, domains, and the overall instrument:

(highest value – lowest value) / number of categories

(5 - 1) / 3 = 1.33

This calculation yielded the following interpretative ranges for mean scores:

1.00 - 2.33: low degree

2.34 - 3.67: moderate degree

3.68 - 5.00: high degree

3.4. Validity of the Study Tool

A rigorous review process involving a panel of 11 seasoned experts in the relevant field of study who provided valuable feedback and recommendations was employed to establish the content validity of the questionnaire. In response to their suggestions, the questionnaire was substantially modified. This iterative refinement process yielded a final questionnaire comprising 45 items, a reduction from the initial 49. Notably, the inter-rater agreement among the expert panel reached 80% indicating a high level of consensus regarding the instrument's content validity.

The researchers conducted a comprehensive correlation analysis to evaluate the questionnaire's construct validity. Table 2 presents full details of the correlation coefficients. The range of correlation coefficients (0.38 to 0.87) suggests a moderate to strong relationship between the items and their respective domains and the overall scale. It indicates good construct validity demonstrating that the items effectively measure the intended constructs within the STEAM approach implementation framework. This rigorous validation ensures the research instrument's reliability and validity reinforcing the study's overall methodological robustness.

Notably, all correlation coefficients were acceptable and statistically significant. Therefore, deleting any item was unnecessary. Table 3 illustrates the correlation coefficient between the domain and the total score and the correlation coefficients between the domains.

Table 2. Correlation coefficients between the items, total score, and the corresponding domains.

Item no.	Correlation coefficient with the domain	Correlation coefficient with the tool	Item no.	Correlation coefficient with the domain	Correlation coefficient with the tool	Item no.	Correlation coefficient with the domain	Correlation coefficient with the tool
1	0.79**	0.67**	16	0.63**	0.55**	31	0.71**	0.68**
2	0.75**	0.57**	17	0.39*	0.51**	32	0.61**	0.57**
3	0.48**	0.46*	18	0.49**	0.53**	33	0.75**	0.68**
4	0.38*	0.42*	19	0.51**	0.55**	34	0.76**	0.69**
5	0.75**	0.70**	20	0.52**	0.73**	35	0.55**	0.57**
6	0.67**	0.51**	21	0.54**	0.41*	36	0.69**	0.53**
7	0.72**	0.65**	22	0.52**	0.55**	37	0.51**	0.55**
8	0.80**	0.67**	23	0.49**	0.49**	38	0.62**	0.45*
9	0.80**	0.64**	24	0.48**	0.69**	39	0.66**	0.55**
10	0.85**	0.72**	25	0.56**	0.68**	40	0.67**	0.70**
11	0.87**	0.81**	26	0.49**	0.45*	41	0.40*	0.53**
12	0.49**	0.53**	27	0.77**	0.76**	42	0.83**	0.76**
13	0.52**	0.42*	28	0.47**	0.55**	43	0.77**	0.76**
14	0.62**	0.49**	29	0.65**	0.39*	44	0.80**	0.83**
15	0.76**	0.65**	30	0.56**	0.57**	45	0.43*	0.46*

Note: *Statistical significance at the (0.05) level.
**Statistical significance at the (0.01) level.

Table 3. Correlation coefficients between domains and the total score.

Domains	Planning	Implementation	Evaluation	Overall score
Planning	1			
Implementation	0.676**	1		
Evaluation	0.625**	0.802**	1	
Overall score	0.858**	0.907**	0.916**	1

Note: ** Statistically significant at the significance level of (0.01).

Table 3 depicts that all correlation coefficients were acceptable and statistically significant indicating an appropriate level of construct validity.

3.5. Reliability

3.5.1. Test-Retest Reliability

The questionnaire was administered twice to a pilot group of 30 mathematics teachers from public schools across all educational directorates in Amman. This group differed from the primary study sample. The second administration occurred two weeks after the initial one. Pearson correlation coefficients were then calculated between the participants' responses from both administrations to assess the instrument's reliability over time.

3.5.2. Internal Consistency Reliability

Cronbach's alpha coefficients were calculated to measure the instrument's internal consistency. Table 4 portrays a comprehensive overview of the reliability metrics.

Table 4. Cronbach's alpha for internal consistency and test-retest reliability for domains and total score.

Domains	Test-retest reliability	Internal consistency
Planning	0.83	0.80
Implementation	0.80	0.79
Evaluation	0.81	0.77
Overall score	0.85	0.82

The resultant reliability coefficients were deemed appropriate for this study indicating satisfactory levels of both temporal stability (test-retest reliability) and internal consistency (Cronbach's alpha). This dual approach to reliability assessment boosts confidence in the research instrument's consistency and dependability strengthening the overall methodological rigor of the study.

3.6. The Interview

The second research instrument included a series of qualitative interviews. The interview sample comprised 25 purposively selected mathematics teachers from public schools in Amman, Jordan. The interview format was based on Anizat (2022) and Al-Qahtani and Al-Kahlan's (2017) studies. The interview initially included two questions but upon the advice of experienced mathematics teachers and subject supervisors, these questions were refined to form a single, comprehensive query as follows:

What challenges do mathematics teachers from their perspective face while implementing the STEAM approach in government schools in Amman, Jordan?

The qualitative interview process was conducted according to recognised methodological steps. The participants were purposefully selected based on the score they had on the questionnaire as they were categorised into groups with low, medium, and high degrees of implementation of the STEAM approach. The researcher contacted each participant to arrange a mutually convenient interview time. The interviews were conducted in a suitable setting at their schools, displaying respect and appreciation for the interviewees. Before the interviews, all participants were informed of the objectives of the study and assured that all data were confidential and would only be used for research purposes. During the interview, responses were transcribed verbatim without alterations. Interviews lasted between 10 and 15 minutes indicating data collection consistency. The researcher employed a coding methodology based on Strauss and Corbin's approach to facilitate data analysis.

a. Close reading: Each interview transcript was carefully and critically examined many times to extract key ideas and themes.
b. Open coding: Ideas and themes mentioned by participants were coded and organised as presented in the interviews.
c. Axial coding: The open codes were reviewed to identify general characteristics and attributes. The main categories were established with sub-ideas incorporated to arrive at final generalised attributes. The researcher ensured that sub-ideas were represented verbatim from interviewee statements.

This rigorous qualitative approach enabled a deep exploration of mathematics teachers' challenges in implementing the STEAM approach complementing the quantitative data collected through the questionnaire.

4. RESULTS

This section summarizes each case followed by the results for the research questions to reply to the main study question concerning the degree of adoption of the STEAM approach by mathematics teachers in teaching grades 4 to 10 in government schools in Amman.

4.1. RQ (1)

The researcher conducted a quantitative analysis by determining the arithmetic means and standard deviations of the teachers' responses to the questionnaire items to address the first research question concerning the extent of STEAM approach implementation in mathematics teaching by math teachers in Amman's government schools. Table 5 presents the analysis results providing a comprehensive overview of the degree of implementation across different domains of the STEAM approach.

Table 5. Arithmetic means and standard deviations of the degree of implementation of the STEAM approach by mathematics teachers.

Ranks	Numbers	Domains	Mean	Standard deviation	Degree of implementation
1	2	Implementation	3.6	0.486	Moderate
2	1	Planning	3.53	0.550	Moderate
3	3	Evaluation	3.47	0.641	Moderate

This tabular presentation enables a clear and concise representation of the data facilitating straightforward interpretation of the results. The arithmetic means provide a measure of central tendency demonstrating the average level of implementation for each domain. Conversely, the standard deviations offer insight into the range of responses within each domain. This quantitative analysis depicts a clear picture of the current status of STEAM approach implementation in mathematics teaching within Amman's government schools as perceived by the mathematics teachers. Regarding the implementation levels, arithmetic means ranged from 3.47 to 3.60 across domains. The implementation domain ranked the highest with a mean of 3.60 and the lowest-ranked domain was evaluation with a mean of 3.47. The overall implementation degree of 3.52 indicates a moderate level.

4.2. RQ (2)

The second research question explored any probable statistically significant differences in demographic variables. Firstly, the arithmetic means and standard deviations for STEAM implementation levels were calculated. The variables under consideration include gender, teaching experience, training courses, and grade levels. Table 6 depicts the results.

Table 6. Arithmetic means and standard deviations of the degree of implementation of the steam approach by mathematics teachers from their perspective based on the variables of gender, teaching experience, training courses, and grade levels.

Variables	Levels of variables	Count	Standard deviation	Mean
Gender	Male	134	0.500	3.49
	Female	170	0.522	3.57
Teaching experience	Less than a year	25	0.546	3.47
	From 1 year to less than 5 years	46	0.507	3.41
	More than 5 years	233	0.508	3.56
Training courses	Attended courses	170	0.492	3.62
	Have not attended courses	134	0.500	3.23
Grade levels	4-6	201	0.54	3.46
	7-10	103	0.47	3.57

This comprehensive analysis provides an understandable representation of STEAM implementation in Amman's mathematics classrooms underscoring both the progress and the remaining challenges. Examining demographic variables offers potential insights into factors impacting implementation levels which could inform targeted interventions and professional development strategies. Table 6 reveals apparent variations in arithmetic means and standard deviations per the degree of STEAM approach implementation in mathematics teaching by educators in Amman's government schools. These variations are presented across categories of gender, teaching experience and training courses.

The researchers conducted a three-way analysis of variance (ANOVA) to determine the statistical significance of arithmetic means. Table 7 displays analysis results and provides insights into the significance of the observed variations across the independent variables.

Table 7 presents no statistically significant gender-based differences ($\alpha = 0.05$) in STEAM approach implementation ($F = 2.378$, $p = 0.124$). The study sample's opinions on implementation degrees in Amman's government schools were consistent across genders with both illustrating equal attitudes. Similarly, no statistically significant grade level-based differences ($\alpha = 0.05$) were present in the STEAM approach implementation ($F = 2.488$, $p = 0.133$). The study sample's opinions on implementation degrees in Amman's government schools were also consistent across grade levels with both depicting equal attitudes. Conversely, statistically significant differences ($\alpha = 0.05$) attributable to training courses ($F = 8.198$, $p = 0.004$) existed favoring those with STEAM-specific training. Furthermore, statistically significant differences ($\alpha = 0.05$) were found for teaching experience ($F = 3.103$, $p = 0.046$). The Scheffe post hoc test was conducted to identify specific pairwise differences between arithmetic means. Table 8 displays the results.

Table 7. Three-way analysis of variance for the effect of gender, teaching experience, training courses, and grades levels on the degree of implementation of the steam approach by mathematics teachers, from their perspective.

Source of variations	Sum of squares	Degrees of freedom	Mean square	F-value	Statistical significance (P-value)
Gender	0.603	1	0.603	2.378	0.124
Teaching experience	1.574	2	0.787	3.103	0.046
Training courses	2.080	1	2.080	8.198	0.004
Grade levels	0.713	1	0.713	2.488	0.133
Error	75.856	299	0.254		
Total	80.429	303			

Table 8. Scheffe post-hoc comparisons for the effect of teaching experience on the degree of implementation of the steam approach by mathematics teachers, from their perspective, in government schools in Amman, Jordan.

Levels of the variables	Mean	Less than 1 year	Between 1 year and 5 years	More than 5 years
Less than 1 year	3.47			
Between 1 year and 5 years	3.41	0.06		
More than 5 years	3.56	-0.10*	-0.16*	

Note: *Statistically significant at the significance level of (0.05).

Table 8 displays statistically significant differences (α=0.05) between the 5 years or more teaching experience group and both less than 1 year and between 1 year and 5 years groups, favoring the most experienced group.

4.3. RQ (3)

The qualitative data obtained from the interview questions were analysed to address the question related to the obstacles faced by mathematics teachers from their perspective while implementing the STEAM curriculum in public education institutions in Amman. Figure 1 presents the results.

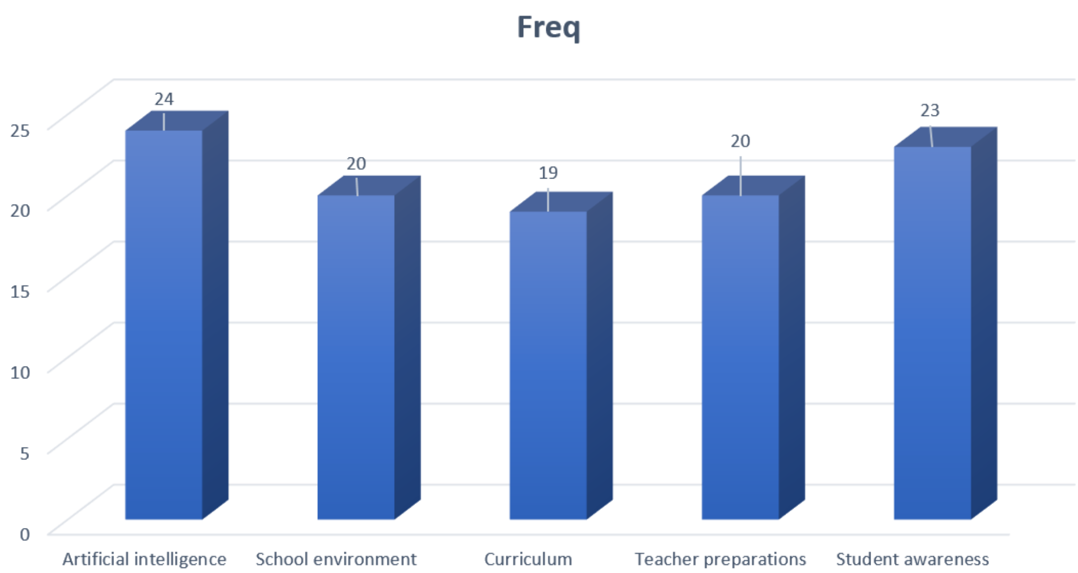

Figure 1. Frequent challenges arising from the analysis of interview questions.

The qualitative results revealed that the sample confirmed that the biggest challenge is using artificial intelligence (AI) in mathematics classes whether by the subject teacher or the students. This challenge has the following two aspects: The first addresses how the teacher deals with AI and benefits from integrating technology with mathematics and achieving integrated teaching. The second aspect is associated with how students use AI as teachers agree that students are savvy in using technology and utilize it to solve homework readily. They use Chat GPT to solve homework not doing it themselves hindering their success in class.

The second category of obstacles involves teacher-related challenges including inadequate pre-service preparation, limited in-service training, heavy workload, reluctance to adopt STEAM, lack of technology skills, and preference for traditional methods. A third category is linked to student-related challenges, encompassing resistance to modern methods, lack of STEAM awareness, poor proficiency in 21st-century skills, low motivation, and inadequate incentives. Furthermore, curriculum-related challenges include a lack of STEAM support in the teacher's guide, inadequate theoretical focus, time constraints, content-level mismatch, misalignment with curriculum, monotonous presentation, neglect of individual differences, and lack of challenging problems. Finally, school or classroom environment-related challenges encompass insufficient equipment, lack of administrative support, an uninspiring environment, overcrowded classrooms, limited resources, and inadequate technology access.

5. DISCUSSION

The objective of this study was to assess the extent to which mathematics teachers in public institutions in Amman from their perspective implement the STEAM methodology in their pedagogical practices. The researcher also aimed to detect the presence of any statistically significant differences (at α= 0.05) in the mean scores of study participants per the extent of STEAM approach implementation in mathematics instruction. The study variables were considered and the obstacles mathematics teachers faced from their perspective while executing the STEAM approach in Amman's public educational institutions were addressed. Mathematics teachers face numerous challenges when implementing the STEAM approach through the preceding analysis. These challenges encompass the difficulties the large class sizes present, which is the norm in government schools as articulated by the math teachers themselves. A large number of students in classes lead to time constraints inevitably. It is not feasible that all students can adequately participate in a 45-minute class period. Students were found to have limited knowledge and a lack of cumulative information leading to severe deficiencies in mathematics which are compounded when they tackle more complex topics. Classrooms often suffer from limited learning resources and having to share devices can hinder progress, especially for students who are not "tech savvy". Furthermore, some students tend to lack seriousness among technological distractions. Overall, a lack of comprehensive understanding of the STEAM concept on behalf of both students and teachers is probable. Teachers are faced with the challenge of overwhelming curriculum content in limited available time, and they may be unfamiliar with new curricula integrating STEAM with mathematics. Finally, many teachers reported having limited experience applying the STEAM's project-based, problem-solving, critical, and creative thinking aspects. Table 5 presents the degree to which math teachers in public institutions in Amman successfully implemented aspects of the STEAM approach in teaching mathematics. This information helps identify which aspects of the STEAM approach are most prevalently implemented and which may require further attention or development. Moderate implementation levels are linked to several factors.

Many teachers preferred traditional teaching methods such as direct instruction and lecturing. Many teachers report being more comfortable with direct instruction through lectures despite all the available technology. This preference stems from the ease of implementation, quick results, and compatibility with existing school environments and resources. Effective implementation of the STEAM approach necessitates high levels of preparedness from teachers and students, adequate material resources and appropriate curriculum design. Teachers also cited their heavy workload for not employing new techniques, claiming they did not have time to design, implement, and evaluate STEAM-based activities. They also discussed contextual challenges such as overcrowded classrooms, limited financial resources and a lack of educational tools and modern technologies. They were concerned about classroom management and poor student attitudes towards learning mathematics. According to the teachers, a major impediment is that they have received inadequate training in STEAM methodologies and have not mastered the concepts involved. Moreover, some teachers mentioned their limited knowledge of interdisciplinary scientific and engineering concepts. Overall, the participant teachers of this study realized the need for collaborative efforts across school elements, including administrators, teachers, and students.

These findings corroborate those of previous studies such as Aldulaymi and Al-Owaidi (2021) presenting moderate levels of STEAM approach implementation in physics teaching in Iraq. Anizat (2022) demonstrated pivotal obstacles to STEAM implementation in mathematics teaching across all areas (student-related, educational environment, and content) in Ajloun Governorate's government schools. Similarly, Popa and Ciascai (2017) and Al-Qahtani and Al-Kahlan (2017) revealed substantial hindrances to STEAM implementation in mathematics instruction leading to elevated challenges.

The findings depict that teacher with more than five years of experience implemented STEAM methodologies more than the other groups. The researcher attributes this finding to the accumulated knowledge, practical experience, and understanding of roles acquired by long-serving teachers with a clearer grasp of modern educational trends, theories, and contemporary teaching strategies. This result contrasts with that of Aldulaymi and Al-Owaidi (2021) who reported no significant experience-based differences in STEAM implementation in Iraq. Moreover, Alkhawaldeh (2017) presented training to teachers in schools in Jordan for sustainable professional on-the-job development confirming that trained teachers can better deal with new developments in teaching strategies.

Table 7 reveals that the uniformity of STEAM implementation across genders is associated with similar work conditions and socio-economic environments in schools. Notably, Jordanian government schools are separate entities for male and female students. This finding aligns with Aldulaymi and Al-Owaidi (2021) who reported no significant gender differences (p>0.05) in STEAM approach implementation in physics teaching in Iraq. The researcher attributes this finding to these teachers' enhanced ability to plan, implement, and assess lessons using the STEAM approach. Their prior knowledge of integrated STEAM methodology and skills in designing activities integrating mathematics with science, engineering, technology and the arts contribute to this positive outcome.

Regarding the third question of mathematics teachers' challenges in implementing STEAM, the most challenging one was how to deal with AI because it has risks and benefits and requires high skills. Students are more adept than teachers at using AI and can benefit from it while doing assignments which are the most challenging. Triplett (2023); Celik (2023) and Citraro, Vitevitch, Stella, and Rossetti (2023) also confirm this finding. These researchers all agreed that AI will find increasing use in education. Therefore, rules must be established for their use so that students do not cheat and fail to achieve the lesson's desired outcomes.

6. CONCLUSION

The results demonstrated that mathematics teachers working in Jordanian public schools have an orientation towards using the STEAM approach. However, they face several challenges. Mathematics teachers provide some activities using the STEAM approach to solve some mathematical problems regardless of gender or class level. Our results revealed that teachers with higher years of experience and those who had taken relevant training courses in STEAM use in teaching were successful. The teacher equipped with these strategies provides a better presentation and a more satisfactory interaction with the learners in the classroom. However, among the challenges these teachers face in this field include the incorrect use of AI and the poor classroom environment for STEAM tools. Additionally, students' awareness of using the STEAM approach is still unclear. Therefore, the teacher cannot provide the optimum practices but is satisfied with the initial attempts.

In a nutshell, this study recommends providing specialized training for teachers on implementing the STEAM approach in mathematics instruction through targeted courses focusing on practical application techniques. The roles of school leaders and educational supervisors must be enhanced to promote STEAM adoption among teachers by offering both financial and non-financial incentives to motivate implementation. Furthermore, the authorities responsible for setting the curriculum must update and adapt the mathematics curricula to align more closely with the STEAM approach ensuring content integration and relevance. Finally, steps must be taken to improve the school environment to support STEAM activities by equipping teachers in Amman's government schools with the necessary resources for effective mathematics instruction utilising the STEAM approach.

7. IMPLICATIONS

The study findings suggest a need for curriculum reforms incorporating STEAM principles more effectively, ensuring that math instruction is interdisciplinary and relevant to real-world applications. The obstacles identified underscore the necessity for enhanced professional development programs. Teachers may require training on STEAM methodologies to feel confident and implement these approaches in their classrooms. Our study also addressed the need for schools to allocate resources associated with materials and technology to support STEAM initiatives. These resources include hands-on tools, access to digital resources, and collaboration opportunities.

This study accentuates STEAM's potential to increase student engagement and interest in mathematics, making learning more interactive and dynamic from the teachers' perspectives. Integrating arts and other disciplines could promote more collaborative teaching approaches, fostering teamwork among teachers to design comprehensive lessons that resonate across subjects. Finally, the findings inform educational policy, advocating for systemic changes and urging STEAM adoption at all education levels. Overall, the study provides valuable insights into both the potential benefits of STEAM in math instruction and the challenges to be addressed for successful implementation.

Funding: This study received no specific financial support.
Institutional Review Board Statement: The Ethical Committee of the Hashemite University, Jordan, approved this study on 5 February 2023 (Ref. No. 42/1/2022/2023).
Transparency: The author states that the manuscript is honest, truthful, and transparent, that no key aspects of the investigation have been omitted, and that any differences from the study as planned have been clarified. This study followed all writing ethics.
Competing Interests: The author declares that there are no conflicts of interests regarding the publication of this paper.

REFERENCES

Abdel Aziz, O. (2005). Obstacles to teaching mathematics for boys and girls in the second intermediate grade. *Journal of Taibah University for Educational Sciences, 1*(1), 1-46.

Al-Ahmedi, M. (2019). The professional competencies required for teachers involved in implementing the STEM approach in schools from their perspective. *Journal of Scientific Research in Education, 11*(20), 181-147.

Al-Ma'afa, N. (2020). Personalized learning according to the STEM approach in continuous education: An experimental study on second grade school students. *Arab Journal of Scientific Publishing, 3*(22), 78-54.

Al-Mohammadi, N. (2018). The effectiveness of teaching according to the STEAM approach in developing the problem-solving ability of female secondary stage students. *International Educational Journal of Specialized Sciences, 7*(1), 130-121.

Al-Muhaysin, I., & Khaja, A. (2015). *Professional development of science teachers in light of the integration of science, technology, engineering, and mathematics (STEM) trend.* Paper presented at the Excellence in Science and Mathematics Education Conference, Excellence Research Center, University.

Al-Qahtani, H., & Al-Kahlan, T. (2017). Obstacles to applying the STEM approach in teaching mathematics in middle schools from the perspective of teachers and supervisors in Asir Region. *Arab Journal of Scientific Research and Publication, 1*(9), 42-23.

Al-Qathami, A. (2016). *The effect of using the STEM Approach to teach mathematics on academic achievement and thinking skills among second grade intermediate students.* Unpublished Master's Thesis, Umm Al-Qura University, Mecca, KSA.

Al-Umairi, F. B. B. (2022). The impact of the STEM approach in teaching mathematics on developing life mathematical problem-solving skills and productive desire among second grade intermediate female students. *Journal of Educational and Social Sciences, 1*(15), 34-32.

Aldosari, H. M. (2015). *The reality of Saudi Arabia's experience in teaching STEAM in light of international experiments.* Paper presented at the The First Conference on Excellence in Science and Mathematics Education, Saudi Arabia.

Aldulaymi, Z. H., & Al-Owaidi, H. M. (2021). *The degree of employing the STEM approach in teaching physics from teachers' perspective in Iraq.* Unpublished Master's Thesis, Faculty of Education Sciences, Middle East University, Jordan.

Alkhawaldeh, A. (2017). School-based teacher training in Jordan: Towards on-school sustainable professional development. *Journal of Teacher Education for Sustainability, 19*(2), 51-68. https://doi.org/10.1515/jtes-2017-0014

Alsanania, S. (2017). *The effect of teaching science using the STEAM approach on developing spatial thinking and acquiring space and astronomy concepts among ninth grade female students.* Unpublished Master's Thesis, Sultan Qaboos University, Muscat, Oman.

Anizat, H. I. (2022). Obstacles to applying the STEM approach in teaching mathematics in government schools in Ajloun Governorate from teachers' perspective. *Journal of Educational and Psychological Sciences, 6*(19), 48-32.

Aqel, M., & Azam, D. (2022). The impact of a developed teaching unit in the science subject according to the STEAM approach on developing mental motivation among a sample of seventh grade female students. *International Journal of Educational and Psychological Studies, 11*(5), 1076-1051.

Asquol, M., & Abu Odeh, M. (2016). The level of mathematical burnout among tenth grade students under the dimensions of mathematical burnout. *Studies Journal, 4*(2), 36-61.

Ayanwale, M. A. (2023). Can experience determine the adoption of industrial revolution 4.0 skills in 21st century mathematics education? *Research in Social Sciences and Technology, 8*(1), 74-91. https://doi.org/10.46303/ressat.2023.6

Ayanwale, M. A., Adelana, O. P., & Odufuwa, T. T. (2024). Exploring STEAM teachers' trust in AI-based educational technologies: A structural equation modelling approach. *Discover Education, 3*(1), 1-22. https://doi.org/10.1007/s44217-024-00092-z

Celik, I. (2023). Towards intelligent-TPACK: An empirical study on teachers' professional knowledge to ethically integrate artificial intelligence (AI)-based tools into education. *Computers in Human Behavior, 138*, 107468. https://doi.org/10.1016/j.chb.2022.107468

Chng, E., Tan, A. L., & Tan, S. C. (2023). Examining the use of emerging technologies in schools: A review of artificial intelligence and immersive technologies in STEM education. *Journal for STEM Education Research, 6*, 385–407. https://doi.org/10.1007/s41979-023-00092-y

Citraro, S., Vitevitch, M. S., Stella, M., & Rossetti, G. (2023). Feature-rich multiplex lexical networks reveal mental strategies of early language learning. *Scientific Reports, 13*(1), 1–12. https://doi.org/10.1038/s41598-022-27029-6

Demetriou, A., Spanoudis, G., Makris, N., Golino, H., & Kazi, S. (2021). Developmental reconstruction of cognitive ability: Interactions between executive, cognizance, and reasoning processes in childhood. *Cognitive Development, 60*, 101124. https://doi.org/10.1016/j.cogdev.2021.101124

Hynes, B., Costin, Y., & Richardson, I. (2023). Educating for STEM: Developing entrepreneurial thinking in STEM (Entre-STEM) in enhancing entrepreneurial mindsets through STEM education. In (pp. 165-194). Cham: Springer International Publishing.

James, J. (2017). Science, technology engineering, and mathematics (STEAM) curriculum and seventh grade mathematics and science achievement. *Journal of Chemical Information and Modeling, 53*(9), 1689–1699.

Kuware', A. (2017). *The impact of using the STEM approach in developing conceptual understanding and creative thinking in mathematics among ninth grade students*. Unpublished Master's Thesis, Islamic University, Gaza, Palestine.

Lou, S.-J., Tsai, H.-Y., Tseng, K.-H., & Shih, R.-C. (2014). Effects of implementing STEM-I project-based learning activities for female high school students. *International Journal of Distance Education Technologies, 12*(1), 52-73. https://doi.org/10.4018/ijdet.2014010104

Manazir, A., & Al-Hanaki, M. (2021). Obstacles to applying the STEM integration approach from the perspective of middle and high school female teachers in Saudi Arabia. *Ain Shams University Journal of Education, 45*(4), 254-221.

Molefi, R. R., & Ayanwale, M. A. (2023). Using composite structural equation modeling to examine high school teachers' acceptance of e-learning after Covid-19. *New Trends and Issues Proceedings on Humanities and Social Sciences, 10*(1), 1-11.

Olivarez, N. (2012). *The Impact of a STEM program on academic achievement of eighth grade students in a South Texas Middle school*. Doctoral Dissertation, Texas A&M University-Corpus Christi.

Popa, R., & Ciascai, L. (2017). Students' attitude towards STEM education. *Acta Didactica Napocensi, 10*(4), 55-62.

Saleh, S., Abu, S., & Abdu, R. (2019). The effectiveness of using the STEM approach in improving the achievement of tenth grade students in mathematics. *Journal of Open University of Jerusalem for Educational and Psychological Research, 28*(10), 112-101.

Schreiber, L. M., & Valle, B. E. (2013). Social constructivist teaching strategies in the small group classroom. *Small Group Research, 44*(4), 395-411. https://doi.org/10.1177/1046496413488422

Suryani, E., Kun, Z., & Haryanto, H. (2023). The implementation of STEM approach (Science, technology, engineering, and mathematics) on science learning at elementary school. *Proceedings Series on Social Sciences & Humanities, 12*, 315-322. https://doi.org/10.30595/pssh.v12i.814

Triplett, W. J. (2023). Addressing cybersecurity challenges in education. *International Journal of STEM Education for Sustainability, 3*(1), 47-67. https://doi.org/10.53889/ijses.v3i1.132

Voskoglou, M. G., & Salem, A.-B. M. (2020). Benefits and limitations of the artificial with respect to the traditional learning of mathematics. *Mathematics, 8*(4), 611. https://doi.org/10.3390/math8040611

Yilmaz, R., & Yilmaz, F. G. K. (2023). Augmented intelligence in programming learning: Examining student views on the use of ChatGPT for programming learning. *Computers in Human Behavior: Artificial Humans, 1*(2), 100005. https://doi.org/10.1016/j.chbah.2023.100005