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The degree of implementing STEM practices among mathematics teachers at the middle school level from the teachers' and educational supervisors' perspectives

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Abstract

The current quantitative study aims to examine the degree of implementation of STEM practices among middle school mathematics teachers from the teachers' and educational supervisors' perspectives. The study also seeks to identify the statistical significance between the responses of teachers and supervisors regarding the degree of implementing STEM practices. STEM is an acronym for the integrative approach among science, technology, engineering and mathematics. The study used a questionnaire that was built based on a four-level Likert scale as a tool for collecting data using the descriptive survey method. Sixty-four middle school mathematics teachers and seven educational supervisors of mathematics participated in the study that took place in Al-Ahsa Governorate, Saudi Arabia. Findings revealed that the participating teachers implemented STEM practices moderately in their classrooms in the main three domains which are lesson evaluation, lesson implementation and lesson planning, respectively. In addition, there are statistically significant differences between the participating teachers and supervisors regarding the degree of implementing the STEM practices in favor of the teachers. The study recommends dedicating sufficient funds for STEM education, creating creative STEM websites and labs and obtaining access to STEM resources and materials. It is concluded that there is a great need for preparing mathematics teachers to apply STEM practices in their classrooms.

Keywords: Educational supervisors, Mathematics classrooms, Mathematics teachers, Middle schools, Teachers' and educational supervisors' perspectives, STEM practices.

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1. Introduction

It can be clearly recognized that most educational systems worldwide are investing considerable attention in terms of developing strategies and teaching methods in order to teach mathematics more effectively. Developing purposeful and effective mathematics teaching and learning can contribute to enhancing students' learning and raising the likelihood of their success [1, 2]. Mathematics has distinct and unique characteristics that distinguish it from other subjects across all educational levels. These characteristics are reflected in its cumulative nature, its rigid structure, its foundations that adhere to logic and proof, its language that combines verbal, symbolic and formal abstraction, its relationship with real-life situations and applications and its laws and theories that are applied in other fields such as physics, chemistry, computer science and engineering Ibrahim [3], Salha and Abusarah [4]. Aloraini [5] argues that mathematics is a scientific and technological discipline that depends on accuracy and abstraction. It requires specialized skills. Various aspects of mathematics have also been used in other fields such as engineering, science, medicine, technology, etc. [6, 7]. Therefore, mathematics needs to be taught using effective and collaborative strategies that integrate mathematical topics with other educational and scientific fields. In recent years, modern educational and teaching trends and practices have emerged in an effort to advance education in general and mathematics in particular. For example, the integrative approach among science, technology, engineering, and mathematics (STEM) is considered one of the most recent educational trends that shows promising results in terms of teaching mathematics effectively. Since STEM refers to four disciplines, each discipline consists of specific specializations and educational aspects: (a) science which includes the nature of science, knowledge, skills, scientific thinking skills, creative thinking approaches, decision-making and scientific trends. (b) Technology which comprises scientific and technical applications, applied engineering and computer science. (c) Engineering which encompasses engineering designs, engineering design-centered models and the principle bases of technological culture. (d) Mathematics which includes a wide range of mathematical fundamentals, mathematical problem-solving and broad essentials [5, 8, 9]. STEM education is considered a purposeful educational approach and an essential interdisciplinary subject since it promotes the idea that these four disciplines should be integrated into the learning process. Such integration has been an important aspect of many recent education reforms including the Next Generation Science Standards (NGSS) [10] and the Common Core State Standards for Mathematics (CCSSM) [11]. It is worth mentioning that STEM education is not just a reform movement in education; it also emphasizes an interdisciplinary approach for preparing a successful generation of students with the necessary knowledge, abilities and skills in the STEM disciplines [12]. In fact, it is debated that STEM education plays a significant role when it comes to enhancing 21st century learning skills [13, 14] especially in the four components of development, including creativity, collaboration, communication and critical thinking [15]. In this context, Kennedy and Odell [16] discussed the current state of STEM education in a comprehensive way by stating the following:

STEM education has evolved into a meta-discipline, an integrated effort that removes the traditional barriers between these subjects and instead focuses on innovation and the applied process of designing solutions to complex contextual problems using current tools and technologies. Engaging students in high quality STEM education requires programs to include rigorous curriculum, instruction and assessment, integrate technology and engineering into the science and mathematics curriculum and also promote scientific inquiry and the engineering design process (p. 246).

From a historical perspective, the concept of STEM was first introduced and originated as an acronym for science, technology, engineering and mathematics in the 1990s by a group of policy makers and educators at the National Science Foundation (NSF) [17]. Many educators and researchers looked at STEM from different points of view and they defined it based on various areas of interest. For example, Tsupros, et al. [18] defined it as a multidisciplinary approach that links scientific concepts to natural phenomena where students can employ science, technology, engineering and mathematics in situations that improve communication between the educational institution and the community, fostering the development of a scientific culture and equipping them for success in the global economy. However, perhaps the most well-known definition of STEM education is the one that is stated in *STEM Lesson Essentials: Integrating Science, Technology, Engineering, and Mathematics* which emphasizes that the four fields of science, technology, engineering and mathematics are no longer separated by traditional boundaries since STEM can be seen as an interdisciplinary approach to education that incorporates these fields into relevant and real-world learning experiences for learners [19].These generally recognised definitions of STEM education seem to concur on the significance of meaningful connections between the various STEM disciplines and relating such integrated disciplines to real-life situations despite some differences in terminology especially when it comes to the terms "multidisciplinary" and "interdisciplinary." The researcher defines STEM procedurally as all the practices that are applied by middle school mathematics teachers that contribute to enhancing the cognitive, practical and conceptual integration among the four fields of the integrative approach (science, technology, engineering and mathematics) while teaching mathematics and are related to the processes of lesson planning, lesson implementation and lesson evaluation in light of this integrative approach.

According to Vasquez, et al. [19], there are four well-known levels of STEM integration, including disciplinary, multidisciplinary, interdisciplinary and transdisciplinary. After some years, although other researchers added two new levels of integration (i.e., intradisciplinary and quasidisciplinary) into the original levels [20], these four levels are still the most well-known and most cited in the literature.

Integrating STEM education into the learning process can lead to a countless number of advantages especially in mathematics classrooms where it is one of the most crucial scientific trends. In fact, it is integrated into the technological construction of the spirit of science and mathematics and it primarily relies on education through the use of digital technology, hands-on activities, experiential learning through research and exploration, practical activities and scientific and logical thinking activities Aloraini [5]. Cinar, et al. [21] assert that STEM education removes barriers across science, technology, engineering and mathematics disciplines and enables students to grasp the world as a whole rather than in parts. Perhaps one of the most important benefits is developing some of the essential and effective skills that are needed for students such as creative problem-solving skills, critical thinking skills, engineering skills, scientific process skills [16, 22], conceptual understanding and self-directed experiences [9]. Moreover, STEM education assists students to increase their self-confidence, stimulate their motivation and enthusiasm towards learning mathematics, develop their comprehension and acquisition of practical skills and improve their academic accomplishments [12]. Developing such skills plays a crucial role in terms of expanding the horizon of knowledge for the students, fostering and maintaining positive attitudes towards STEM fields and pursuing STEM-related careers. Consequently, it is crucial to successfully incorporate STEM activities and practices into mathematics instruction in order to promote an influential teaching of mathematics and mathematics teachers take responsibility for ensuring that such integration occurs.

The National Council of Teachers of Mathematics (NCTM) and the National Council of Supervisors of Mathematics (NCSM) recognize the significance of addressing STEM disciplines at all educational levels (pre-k, elementary, middle, and secondary) and emphasize the importance of a robust mathematical foundation as the focal point of STEM education [23]. Mathematics requires competent teachers who possess both knowledge and pedagogy that enable them to teach in an efficient and effective way [24]. Mathematics teachers are strongly encouraged to consider STEM practices in their teaching styles since such practices have been showing promising results in terms of enhancing students' learning. Kennedy and Odell [16] argue that the STEM vision must include all students and teachers and have access to the appropriate professional development opportunities to help them prepare to guide their students towards obtaining STEM literacy. This integrative approach is essential for mathematics teachers to comprehend and therefore to apply due to the fact that it is one of the approaches that have been proven to be effective and successful in building knowledge and improving students' achievement levels. Additionally, it calls for mathematics teachers to receive training in a wide range of skills such as using various teaching strategies including project-based learning, brainstorming, collaborative learning, self-learning and digital learning. Other influential skills also comprise management skills for managing digital learning communities, designing and using traditional and digital educational materials and understanding the connections among mathematics and other educational and scientific fields. Thus, STEM practices are strongly recommended to be taken into account when teaching mathematics to students.

Researchers have noticed a discrepancy and hesitancy in the teachers' attitudes towards STEM education in the middle school mathematics teachers based on his experience and interaction with them. They have been participating in organizing and conducting many professional development workshops, research projects and modern teaching methods that are all related to STEM education. Interestingly, researchers conducted a limited exploratory investigation with four middle school mathematics teachers regarding their STEM practices and they found and observed shortcomings in the teachers' teaching performances with regard to employing STEM practices. In addition, the current seminars, programs, training sessions and professional development workshops are insufficient to equip teachers with the necessary knowledge to implement STEM practices and comprehend this field's importance for the future of education. As far as the researcher knows, there have been no studies that have discussed the degree of employing STEM practices among middle school mathematics teachers. Similarly, the researcher has not come across studies that investigated such an area of study from the mathematics teachers' and educational supervisors' perspectives. Consequently, the current study was conducted due to the gaps mentioned above and the scarcity of literature with respect to examining the degree of employing STEM practices in mathematics classrooms. The overarching goal of the current study is to examine the degree of implementation of STEM practices among middle school mathematics teachers from the teachers' and educational supervisors' perspectives. It also aims to identify the significance of the statistical differences between the responses of teachers and supervisors regarding the degree of implementing STEM practices among mathematics teachers at the middle school level. More specifically, the current study aims to answer the following questions:

- To what degree do middle school mathematics teachers implement STEM practices from the teachers' and educational supervisors' perspectives?
- Are there statistically significant differences at the significance level (0.05) between the responses of teachers and supervisors regarding the degree of implementing STEM practices among mathematics teachers at the middle school level?

1.1. Importance of the Study

The theoretical significance of the study is to shed light on the practices of STEM and the degree of their application by middle school mathematics teachers. Furthermore, the practical significance of the study consists of the following:

- Encouraging middle school mathematics teachers to self-evaluate their teaching performances and develop their performances according to a list of STEM practices that the current study revealed.
- Assisting middle school mathematics teachers to learn more about STEM practices.
- Informing the educational supervisors and those who oversee the professional development programs for middle school mathematics teachers with respect to designing programs and training courses about how to apply STEM practices in teaching mathematics.
- Directing the attention of researchers towards conducting more research and scientific studies that include STEM practices in mathematics education.

- Enriching the literature as well as the scientific and research communities with the new effective trends in mathematics education as there is a scarcity of research sought at identifying the degree of applying STEM practices among mathematics teachers.

2. Literature Review

Several studies have used some aspects of the integrative STEM approach in an attempt to examine the teaching practices of mathematics teachers. For instance, Alhabashneh [25] and Algamdi [26] conducted similar descriptive studies that aimed to evaluate elementary school mathematics teachers' teaching practices according to the STEM principles and standards that were prepared and designed by the researchers. Alhabashneh's study consisted of 132 teachers whereas Algamdi's study consisted of 25 teachers. Both studies revealed that the participating teachers applied STEM principles in their classrooms at the medium level in the domains of lesson preparation and planning as well as lesson design and implementation. Furthermore, participants in Alhabashneh's research applied STEM principles at the medium level in the lesson managing and evaluating domain whereas participants in Algamdi's research applied STEM principles at the low level in the same domain. Some recommendations from these studies include providing mathematics teachers with professional development programs focused on how to implement STEM practices and activities with the students effectively as well as assisting mathematics teachers on how to design lessons through interactive classes and virtual reality environments. Similarly, AlKhateeb [12] conducted a descriptive study with the goal of analyzing mathematics teachers' instructional strategies using the integrative STEM approach. Alkhateeb's study included 30 teachers and it indicated that there are seven practices performed by the mathematics teachers at a medium level and 14 practices at a low level consistent with STEM. The results also revealed that there were not statistically significant differences between such practices attributed to qualifications and years of experience variables. However, Alshehri [27] carried out a quasi-experimental study to ascertain the efficacy of a training program created based on STEM instruction in boosting the creative teaching methods of mathematics teachers. Thirty-three secondary school mathematics teachers participated in the study. The study concentrated on four domains including creative teaching planning, creative teaching strategies, learning management using creative strategies and evaluating learners' accomplishments applying creative strategies. Alshehri's study revealed that there were statistically significant differences between the mean scores of the teachers in the pre- and post- application of the program in favor of the post application. These findings indicate that the suggested training program was successful and promising. A growing number of studies have investigated the effectiveness of considering integrative STEM instruction in the learning process. For example, Salha and Abusarah [4] conducted a quasi-experimental study to investigate the impact of using a proposed STEM-oriented approach on students' achievement in mathematics. Forty-five tenth grade students participated in the study and they were divided into two groups: experimental and control. The findings of the study showed that there were statistically significant differences in the post-achievement test in favor of the experimental group that was exposed to the STEM approach. In a similar investigation and for the same purpose, Alanzi and Alsaadon [28] conducted their study with 32 students from the 11th and 12th grades. The study revealed that there were statistically significant differences in the mean scores between the two groups in favor of the experimental group which studied according to the STEM approach. Furthermore, other studies showed the positive impacts of STEM strategies on developing problem-solving skills for middle and secondary school students in mathematics classrooms [29-31]. Findings from these studies showed that there were significant statistical differences in the mean scores between the experimental group and the control group on the post-test in favor of the experimental group. The researchers recommended the adoption of the process of designing mathematics lessons and activities in accordance with STEM approaches and training teachers on how to apply STEM practices in mathematics classrooms accordingly.

Especially in the field of mathematics, it appears as though the literature discussed above has proven the effectiveness of STEM approaches and practices in providing students with sophisticated mathematical knowledge and effective skills, developing positive attitudes towards STEM domains and strengthening mathematics teaching and learning. In spite of the global recognition of the positive impacts of STEM in education, its implementation and instructional practices have remained limited [32, 33]. Furthermore, although many educational systems around the world including the Saudi educational system, strive to promote this recent trend in mathematics education, mathematics teachers in the Kingdom of Saudi Arabia might not recognize the importance of implementing this trend with their students in mathematics classrooms or might apply some of its practices insufficiently or incorrectly. Many studies that were conducted to examine middle and secondary school mathematics teachers' instructional practices in the Kingdom of Saudi Arabia such as Madani [34], Almohammedy [30], Alqahtani and Alkahlan [35], Alsaeed [31] and Alshehri [27] showed that most of those teachers depend mainly on traditional teaching methods to teach mathematics lessons and they also hesitate to implement STEM practices. In addition, the studies strongly recommend that mathematics teachers be encouraged to take STEM-oriented activities and instructional practices into account when it comes to teaching mathematics topics effectively and productively. Therefore, there is a great need for mathematics teachers to consider integrative STEM approaches in their classrooms in order to assist students in reaching their full potential.

3. Methodology

The researcher used the descriptive survey method considering the nature of the study in order to achieve the main goal of the study which is to examine the degree of implementing STEM practices among the middle school mathematics teachers from the teachers' and educational supervisors' perspectives. Alassaf [36] defined the descriptive survey research method as "a type of research through which all members of the research community or a large sample of them are interrogated with the aim of describing the studied phenomenon" (p. 191).

3.1. Study Population and Sample

The population of the current study comprised all mathematics teachers and educational supervisors of mathematics for the middle school level in Al-Ahsa Governorate for the academic year 1442/1443 AH whose number is 219 teachers and nine educational supervisors according to the statistics of the Educational Supervision Department of the General Administration of Education in Al-Ahsa Governorate. The study sample consisted of 64 mathematics teachers and seven educational supervisors of mathematics for the middle school level in Al-Ahsa Governorate who was selected randomly.

3.2. Study Instrumentation

The questionnaire was relied upon as a tool for the study and it was built according to several steps to accomplish the goals of the study. First, the researcher examined the lists reached by many studies, scientific books and Arab and international educational literature that are related to STEM practices and activities for mathematics teachers. Then, the researcher determined the domains of the teaching practices in light of the STEM practices for middle school mathematics teachers which consisted of three main domains: lesson planning, lesson evaluation and lesson implementation. After determining the main domains, the researcher built the items related to STEM practices into a list according to the three domains which contained 30 items distributed over the domains. Then, the initial list was presented to seven experienced and distinguished professors who work as faculty members in Saudi universities in the departments of Curriculum and Instruction and Mathematics Education in order to benefit from their experiences to enhance the initial list. The researcher modified and rephrased some of the items based on the experts' recommendations and opinions. Finally, the researcher converted the list to its final form and converted it into a questionnaire (the study tool). The items of the questionnaire were distributed over the three domains as the domain of lesson planning included 10 phrases, the domain of lesson implementation included 12 phrases and the domain of lesson evaluation included 8 phrases. In an attempt to respond to the questionnaire and identify the degree of implementing STEM practices among the participating middle school mathematics teachers, a four-level Likert scale was used which contains four levels (first level: highly implanted, second level: moderately implemented, third level: slightly implemented and fourth level: never implemented).

3.2.1. The External Validity of the Instrument: Face Validity

The researcher gave the instrument in its initial form to seven experienced and distinguished professors whose educational areas of interest varied between curriculum and instruction, mathematics education, STEM education and mathematics to verify the external validity of the instrument. After reviewing the opinions of the arbitrators, the researcher modified, rephrased, deleted and added some of the items until the instrument was built in its final form. Therefore, the instrument has become valid for measuring what it was prepared for.

3.2.2. The Content Validity (Internal Consistency) of the Instrument

After confirming the external validity of the instrument, the researcher measured the content validity of the study sample by calculating the Pearson correlation coefficient to measure the relationship between the items of the questionnaire and the total score of the domain to which it belongs. Accordingly, all the correlation coefficients between the scores of the items and the scores of their domains were positive and statistically significant at the significance levels (0.01) and (0.05) and this indicates the validity of their consistency with their domains (see Table 1).

Table 1.
Pearson correlation between the items of the questionnaire and the total score of their domains.

Domains	No.	The correlation coefficient	No.	The correlation coefficient
Lesson planning	1	0.9551**	6	0.9546**
	2	0.9837**	7	0.9621**
	3	0.9160**	8	0.9841**
	4	0.9516**	9	0.9837**
	5	0.8763**	10	0.9469**
Lesson implementing	11	0.9012**	17	0.9293**
	12	0.9045**	18	0.9019**
	13	0.8357**	19	0.9254**
	14	0.9234**	20	0.8853**
	15	0.9154**	21	0.9546**
	16	0.8857**	22	0.9423**
Lesson evaluating	23	0.8947**	27	0.8188**
	24	0.9368**	28	0.9234**
	25	0.8917**	29	0.9353**
	26	0.9120**	30	0.8627**

Note: ** Correlation is significant at the 0.01 level (2-tailed)

Additionally, the correlation coefficients between the questionnaire's domain scores and the overall score of the questionnaire were computed by the researcher and all of them were statistically significant at the significance level (0.01) and (0.05) which suggests that the validity of the instrument is high (see Table 2). Furthermore, the researcher computed the correlation coefficients between the sum of the domains and the questionnaire's overall score and they were all statistically significant at the significance level (0.01) which shows that the instrument is highly valid (see Table 3).

Table 2.
Pearson correlation between the items of the questionnaire and the total score of the questionnaire.

No.	The correlation coefficient	No.	The correlation coefficient	No.	The correlation coefficient
1	0.9436**	11	0.9492**	21	0.9495**
2	0.9431**	12	0.9280**	22	0.9206**
3	0.8856**	13	0.8141**	23	0.8914**
4	0.9427**	14	0.9168**	24	0.9062**
5	0.8477**	15	0.8903**	25	0.9287**
6	0.9207**	16	0.8701**	26	0.8887**
7	0.9165**	17	0.9376**	27	0.7818**
8	0.9511**	18	0.8560**	28	0.8914**
9	0.9431**	19	0.8930**	29	0.8672**
10	0.9632**	20	0.8701**	30	0.8288**

Note: ** Correlation is significant at the 0.01 level (2-tailed)

Table 3.
Pearson correlation between the total of the domains and the total score of the questionnaire.

Domains	The correlation coefficient
Lesson planning	0.9735**
Lesson implementing	0.9897**
Lesson evaluating	0.9729**

Note: ** Correlation is significant at the 0.01 level (2-tailed).

3.2.3. Reliability of the Instrument

To measure the reliability of the instrument, the researcher used Cronbach's alpha coefficient and it was found that the total reliability coefficient for the instrument domains was 0.99 which indicates that the study instrument shows a high degree of reliability (see Table 4).

Table 4.
Cronbach's alpha for the reliability of the domains of the questionnaire.

Domains	No. of items	Alpha
Lesson planning	10	0.99
Lesson implementing	12	0.98
Lesson evaluating	8	0.97
All item	30	0.99

Note: Pilot sample: n=15.

3.3. Procedure

The researcher began conducting the study by distributing the research instrument (a questionnaire) to the middle school mathematics teachers and their educational supervisors after measuring its reliability and validity. The questionnaire consisted of 30 items based on STEM teaching practices and these items were distributed over the three essential domains: lesson planning , lesson implementation and lesson evaluation. Participants were encouraged to select the option that represented the teachers' implementation of STEM practices as the questionnaire contained four items of selection: Highly implemented, moderately implemented, slightly implemented and never implemented. The researcher also encouraged the participants to detect accuracy in filling out the questionnaire taking into consideration that the answers will be used for scientific and research purposes only. Once the questionnaires were received, the researcher began analyzing the data.

3.4. Data Analysis

Several data analysis procedures were employed to analyze the data and determine the values for the study. Examples of such procedures include means, standard deviations, frequencies and percentages of frequencies. Moreover, additional procedures comprised Pearson correlation, Cronbach's alpha, t-test and Mann-Whitney test.

The researcher determined the gradient of the categories used in the questionnaire in an attempt to explain the data more effectively. More specifically, for the questionnaire, all items were based on a four-item Likert scale (i.e., highly implemented, moderately implemented, slightly implemented and never implemented) and the highest grade was given 4 degrees and the lowest grade was given 1 degree. The range calculated for the scale was 4-1 = 3 and then this number was divided by the total number of the categories 4 which gave 3/4 = 0.75 which was the length of each category of the four scales. Finally, the length of the category was added to the lowest grade of the scale which was 1. Thus, the first category was calculated to be 1 to 1.75, the second category was calculated to be 1.76 to 2.50, the third category was calculated to be 2.51 to 3.75 and the fourth category was calculated to be 3.76 to 4 (see Table 5).

Table 5.
Distribution according to the gradient of the categories used in the questionnaire.

Description	Range of the mean
Highly implemented	3.76-4.00
Moderately implemented	2.51-3.75
Slightly implemented	1.76-2.50
Never implemented	1.00-1.75

4. Results

The overarching goal of the study is to examine the degree of implementation of STEM practices among mathematics teachers at the middle school level from the teachers' and educational supervisors' perspectives. Therefore, this section presents the findings of the study. The findings are exhibited based on the research questions of the study.

4.1. Findings Related to the First Research Question

The first research question focuses on the degree of implementing the STEM practices: To what degree do middle school mathematics teachers implement the STEM practices from the teachers' and educational supervisors' perspectives? As the instrument of the study consists of three main domains, including lesson planning, lesson implementation and lesson evaluation, the findings of this question are presented according to these domains. For each domain, means, standard deviations, frequencies and percentages of frequencies are computed.

Table 6.
Means, standard deviations, frequencies and percentages of the responses regarding the degree of implementing STEM practices in the lesson planning domain.

Ser no.	Items		Highly implemented	Moderately implemented	Slightly implemented	Never implemented	Mean	Std. deviation	Rank
1	I plan the daily lessons in a way that supports the integration of the STEM fields.	Freq.	21	26	11	13	2.77	1.07	1
		%	29.6	36.6	15.5	18.3			
2	I formulate clear objectives for the lessons based on STEM integration.	Freq.	20	28	9	14	2.76	1.08	2
		%	28.2	39.4	12.7	19.7			
3	I analyze the subject content of the lessons into the mathematical knowledge components (Procedural and conceptual) that support the integration of STEM fields.	Freq.	18	27	14	12	2.72	1.03	4
		%	25.4	38.0	19.7	16.9			
4	I design open-ended learning situations based on STEM practices that allow inferring multiple correct answers.	Freq.	19	23	14	15	2.65	1.10	6
		%	26.8	32.4	19.7	21.1			
5	I design educational activities that require students to research and examine STEM topics.	Freq.	14	25	17	15	2.54	1.04	10
		%	19.7	35.2	23.9	21.1			
6	I prepare questions that encourage students to discover the relationship among STEM fields.	Freq.	19	24	13	15	2.66	1.09	5
		%	26.8	33.8	18.3	21.1			
7	I prepare the learning environment based on the real-life context in a way that integrates the fields of STEM.	Freq.	18	22	16	15	2.61	1.09	9
		%	25.4	31.0	22.5	21.1			
8	I select teaching tools that take into account the integration of STEM fields.	Freq.	18	24	14	15	2.63	1.09	7
		%	25.4	33.8	19.7	21.1			
9	I identify a variety of assessment methods that aim to explore commonalities among STEM fields.	Freq.	17	27	11	16	2.63	1.09	7
		%	23.9	38.0	15.5	22.5			
10	I identify certain types of tasks for closing the lesson in a way that promotes the integration of STEM fields.	Freq.	21	26	8	16	2.73	1.12	3
		%	29.6	36.6	11.3	22.5			
Mean* for total							2.67	0.97	

Note: * The mean of 4 degrees.

4.1.1. First Domain: Lesson Planning

Looking at Table 6, it is obvious that the means of the items regarding the degree of implementing STEM practices in the lesson planning domain ranged from 2.54 to 2.77 which means that almost all the items in this domain were moderately implemented by the participating mathematics teachers. In addition, the total mean for the lesson planning domain was (M = 2.67, SD = 0.97) which also assures that the items in this domain were moderately implemented.

According to Table 6, the mean values of the items with respect to the degree of implementing STEM practices among mathematics teachers at the middle school level in the lesson planning domain are varied. For example, the first item "I plan the daily lessons in a way that supports the integration of the STEM fields" was ranked first since the mean value for this item was (M = 2.77, SD = 1.07). The second item "I formulate clear objectives for the lessons based on STEM integration" was ranked second as the mean value for this item was (M = 2.76, SD = 1.08). However, the fifth item "I design educational activities that require students to research and examine STEM topics" was ranked tenth and last as the mean value for this item was (M = 2.54, SD = 1.04).

Table 7.
Means, standard deviations, frequencies and percentages of the responses regarding the degree of implementing STEM practices in the lesson implementing domain.

Ser no.	Items		Highly implemented	Moderately implemented	Slightly implemented	Never implemented	Mean	Std. deviation	Rank
1	I use appropriate lesson preparation techniques consistent with the integration of STEM fields.	Freq.	24	23	12	12	2.83	1.08	6
		%	33.8	32.4	16.9	16.9			
2	I introduce the lesson in a way that supports the integration of STEM fields.	Freq.	26	18	14	13	2.80	1.13	7
		%	36.6	25.4	19.7	18.3			
3	I use modern learning strategies that develop higher-order thinking skills (e.g., problem solving, project-based learning).	Freq.	18	32	15	6	2.87	0.89	5
		%	25.4	45.1	21.1	8.5			
4	I implement the contrasting cases strategy (Situations whose outcomes are unexpected and surprising to students) for connecting STEM concepts.	Freq.	10	31	18	12	2.55	0.94	11
		%	14.1	43.7	25.4	16.9			
5	I use mathematical tools and technology to develop a conceptual understanding of the mathematical ideas included in the lesson in view of STEM integration.	Freq.	21	21	19	10	2.75	1.04	8
		%	29.6	29.6	26.8	14.1			
6	I employ geometric designs to highlight the relationship among the STEM fields.	Freq.	15	26	14	16	2.56	1.07	9
		%	21.1	36.6	19.7	22.5			
7	I employ technological models based on the basics of STEM integration that take into account the individual differences among students.	Freq.	20	19	13	19	2.56	1.17	9
		%	28.2	26.8	18.3	26.8			
8	I use virtual reality techniques to display mathematical problems according to STEM integration.	Freq.	13	27	11	20	2.46	1.09	12
		%	18.3	38.0	15.5	28.2			
9	I ask classroom questions that aim to stimulate students' thinking about connecting STEM fields.	Freq.	23	29	8	11	2.90	1.03	4
		%	32.4	40.8	11.3	15.5			
10	I employ mathematical formulas and rules in a way that integrates the fields of STEM.	Freq.	25	25	11	10	2.92	1.04	3
		%	35.2	35.2	15.5	14.1			
11	I relate mathematical ideas and concepts to real-life situations regarding STEM topics.	Freq.	27	25	11	8	3.00	1.00	1
		%	38.0	35.2	15.5	11.3			
12	I close the lesson in an appropriate manner that clarifies its most prominent elements and concepts and enhances the integrative relationship among STEM fields.	Freq.	26	23	13	9	2.93	1.03	2
		%	36.6	32.4	18.3	12.7			
Mean* for total							2.76	0.89	

Note: * The mean of 4 degrees.

4.1.2. Second Domain: Lesson Implementation

According to Table 7, it can be clearly seen that the means of the items regarding the degree of implementing STEM practices in the lesson implementation domain ranged from 2.46 to 3.00. More specifically, almost all the items in this domain were moderately implemented by the participating mathematics teachers except for one item that was slightly implemented. Moreover, the total mean for the lesson implementing domain was M = 2.76, SD = 0.89 which assures that the items in this domain were moderately implemented.

According to Table 7, the mean values of the items concerning the degree of implementing STEM practices among mathematics teachers at the middle school level in the lesson implementing domain are varied. For instance, the 11th item "I relate mathematical ideas and concepts to real-life situations regarding STEM topics" was ranked first as the mean value for this item was (M = 3.00, SD = 1.00). The 12th item "I close the lesson in an appropriate manner that clarifies its most prominent elements and concepts and enhances the integrative relationship among STEM fields" was ranked second since the mean value for this item was (M = 2.93, SD = 1.03). However, the eighth item "I use virtual reality techniques to display mathematical problems according to STEM integration" was ranked 12th and last as the mean value for this item was M = 2.46, SD = 1.09 .

Table 8.
Means, standard deviations, frequencies and percentages of the responses regarding the degree of implementing STEM practices in the lesson evaluating domain.

Ser no.	Items		Highly implemented	Moderately implemented	Slightly implemented	Never implemented	Mean	Std. deviation	Rank
1	I use a variety of assessment methods (e.g., peer assessment, portfolios, concept maps) based on students' interests in STEM topics.	Freq.	20	23	17	11	2.73	1.04	7
		%	28.2	32.4	23.9	15.5			
2	I use open-ended assessment tools according to STEM integration.	Freq.	9	30	16	16	2.45	0.98	8
		%	12.7	42.3	22.5	22.5			
3	I encourage students to use self-assessment based on the integrative relationship among STEM fields for evaluating projects and experiences.	Freq.	18	29	14	10	2.77	0.99	6
		%	25.4	40.8	19.7	14.1			
4	I use a variety of assessment activities that promote connections among STEM fields.	Freq.	20	29	9	13	2.79	1.05	5
		%	28.2	40.8	12.7	18.3			
5	I use virtual assessment platforms to evaluate students' solutions and projects.	Freq.	26	22	15	8	2.93	1.02	3
		%	36.6	31.0	21.1	11.3			
6	I apply the types of assessment (pre-assessment, diagnostic, formative and summative) to evaluate students' learning based on STEM integration.	Freq.	22	28	9	12	2.85	1.05	4
		%	31.0	39.4	12.7	16.9			
7	I use feedback to enhance the learning process in light of STEM integration.	Freq.	29	24	8	10	3.01	1.05	1
		%	40.8	33.8	11.3	14.1			
8	I prepare a detailed remedial plan for students to reinforce strengths and improve weaknesses based on the results of the evaluation.	Freq.	26	25	12	8	2.97	1.00	2
		%	36.6	35.2	16.9	11.3			
Mean* for total							2.81	0.87	

Note: * The mean of 4 degrees.

4.1.3. Third Domain: Lesson Evaluating

According to Table 8, it is clear that the means of the items regarding the degree of implementing the STEM practices in the lesson evaluation domain ranged from 2.45 to 3.01. More specifically, almost all the items in this domain were moderately implemented by the participating mathematics teachers except for one item that was slightly implemented. Furthermore, the total mean for the lesson evaluation domain was M = 2.81, SD = 0.87 which assures that the items in this domain were moderately implemented.

According to Table 8, the mean values of the items with regard to the degree of implementing STEM practices among mathematics teachers at the middle school level in the lesson evaluation domain are varied. For example, the seventh item "I use feedback to enhance the learning process in light of STEM integration" was ranked first since the mean value for this item was M = 3.01, SD = 1.05. The eighth item "I prepare a detailed remedial plan for students to reinforce strengths and improve weaknesses based on the results of the evaluation" was ranked second as the mean value for this item was M = 2.97, SD = 1.00. However, the second item "I use open-ended assessment tools according to STEM integration" was ranked eighth and last since the mean value for this item was M = 2.45, SD = 0.98.

Table 9.
Means and standard deviations of the participants' responses regarding the degree of implementing STEM practices in the three main domains.

Domains	Mean*	Standard deviation	Rank
Lesson planning	2.67	0.97	3
Lesson implementing	2.76	0.89	2
Lesson evaluating	2.81	0.87	1
Total	2.75	0.88	

Note: * The mean of 4 degrees.

4.1.4. Comparison of the Main Domains

As a comparison of the main domains considered in the current study (see Table 9), it appears as though the lesson evaluating domain was ranked first (M = 2.81, SD = 0.87), the lesson implementing domain was ranked second (M = 2.76, SD = 0.89) and the lesson planning domain was ranked third (M = 2.67, SD = 0.97). In addition, the total mean for all the domains combined equals (M = 2.75, SD = 0.88). These values mean that STEM practices in all three domains discussed in the study were implemented moderately.

4.2. Findings Related to the Second Research Question

The second research question focuses on whether there are statistically significant differences among the respondents: Are there statistically significant differences at the significance level (0.05) between the responses of teachers and supervisors regarding the degree of implementing STEM practices among mathematics teachers at the middle school level?

To address this question, the researcher employed a T-test to find differences between the two independent groups to determine the differences between the teachers' and supervisors' responses about the degree of applying STEM practices among mathematics teachers at the middle school level. Table 10 shows the findings obtained.

Table 10.
T-test for the significance of the differences between the responses of teachers and supervisors regarding the degree of implementing STEM practices.

Domains	Participants	N	Mean	Standard deviation	T-value	Sig.
Lesson planning	Teachers	64	2.81	0.91	3.90	0.000 (0.01)
	Supervisors	7	1.43	0.56		
Lesson implementing	Teachers	64	2.87	0.86	3.39	0.001 (0.01)
	Supervisors	7	1.75	0.51		
Lesson evaluating	Teachers	64	2.89	0.86	2.40	0.019 (0.05)
	Supervisors	7	2.09	0.59		
Total	Teachers	64	2.86	0.85	3.43	0.001 (0.01)
	Supervisors	7	1.73	0.41		

It is obvious from Table 10 that the values of (T) are significant at the level of (0.0 or less in the three domains: (lesson evaluating, lesson implementing and lesson evaluating) which indicates that there are statistically significant differences between the responses of teachers and supervisors about the degree of application of middle school mathematics teachers to STEM practices and these significant differences were in favor of the teachers.

Since there is a difference with respect to the total number of study participants (64 teachers and 7 supervisors), the researcher conducted the Mann-Whitney test in order to further examine the differences among the participants. Table 11 shows the findings obtained.

Table 11.
NPAR-test (Mann-Whitney) for the significance of the differences between the responses of teachers and supervisors regarding the degree of implementing STEM practices.

Domains	Participants	N	Mean rank	Sum of ranks	Z-value	Sig.
Lesson planning	Teachers	64	38.64	2473.00	55.00	0.001 (0.01)
	Supervisors	7	11.86	83.00		
Lesson implementing	Teachers	64	38.52	2465.00	63.00	0.002 (0.01)
	Supervisors	7	13.00	91.00		
Lesson evaluating	Teachers	64	38.16	2442.00	86.00	0.008 (0.01)
	Supervisors	7	16.29	114.00		
Total	Teachers	64	38.48	2463.00	65.00	0.002 (0.01)
	Supervisors	7	13.29	93.00		

It is clear from Table 11 that the values of Z are significant at the level of 0.05 specifically at the level of 0.01 in the three domains: (lesson evaluating, lesson implementing and lesson evaluating). These values indicate that there are statistically significant differences between the responses of teachers and supervisors about the degree of application of middle school mathematics teachers to STEM practices and these significant differences were in favor of the teachers.

5. Discussion

The study's findings demonstrated that the participants' adoption and implementation of STEM practices in mathematics classes were at a moderate level. This means that STEM practices were not implemented sufficiently or perhaps not well by the study sample in mathematics classrooms. These findings align with the findings obtained by Alhabashneh [25] who found that the participating teachers employed STEM principles at the medium level in the domains of lesson preparation and planning, lesson designing, implementation, lesson management and evaluation. Similarly, the study's findings also align with the study conducted by Algamdi [26] who revealed that the participating teachers applied STEM principles at the medium level in the same domains mentioned previously in Alhabashneh's research except the lesson managing and evaluating domain whereas participants in Algamdi's research implemented STEM principles at the low level. Furthermore, the findings of the current study align with the findings obtained by AlKhateeb [12] which indicated that there are seven STEM practices performed by the mathematics teachers at a medium level. However, the current study contradicts Alkhateeb's study with the other 14 different STEM practices that showed low levels.

The researcher interprets that the sample of the study might have a moderate level with respect to implementing the STEM practices because of a scarcity of forums, seminars, symposiums and conferences introducing integrative STEM education and its related practices and how to use such practices for teaching and learning mathematics based on the findings mentioned previously. Moreover, from the researcher's point of view as he has been interacting with many mathematics teachers, there is a noticeable lack of professional development programs, workshops and training sessions for encouraging mathematics teachers to practice employing STEM activities and practices in their classrooms. In the current study, although the majority of the participants had more than 15 years of teaching experience, 85.9% of them had not attended workshops or training sessions connected to integrative STEM education, according to the participating teachers' responses. In addition, there are few Arab websites and applications dedicated to STEM education. Interestingly, when the researcher conducted brief interviews with some of the participating teachers, he discovered that some of the participants had never heard of integrative STEM education whereas others had employed STEM practices with their students but were unaware that these practices were STEM-related. In fact, the Ministry of Education in the Kingdom of Saudi Arabia makes relentless attempts to encourage the use of STEM practices in education in general and in mathematics education in particular. However, these initiatives are still in their early stages.

The findings also illustrated that there were statistically significant differences between the responses of teachers and supervisors with regard to the degree of application of the participating mathematics teachers to the STEM practices and these significant differences were in favor of the teachers. The researcher believes these findings to be convincing since mathematics teachers are responsible for instructing students in mathematics concepts and interacting with them in mathematics classrooms. To the researcher's knowledge, there have been no studies examining the significance of the statistical differences between the responses of teachers and supervisors regarding the degree of employing STEM practices among mathematics teachers at the middle school level. Thus, the current study can be considered the first of its kind in the Kingdom of Saudi Arabia to investigate such an area.

6. Recommendations

The findings of this study validate the need to have more studies in integrative STEM education. The researcher strongly recommends that the Ministry of Education in the Kingdom of Saudi Arabia dedicate sufficient funds for STEM education in order to create creative STEM websites and labs that contain effective resources and materials for the teachers to use in their classrooms considering the findings of the current study. It is important that all schools have access to these STEM resources and materials. Additionally, it is recommended to hold professional development programs, training courses and workshops to prepare mathematics teachers for using STEM practices in their classrooms and assist them in developing positive attitudes towards integrative STEM education.

Mathematics teachers who are involved in STEM education deliver mathematics topics with an inventive and creative approach which in turn encourages students to come up with more original ideas and be more imaginative. There should be more extra-curricular activities and programs offered alongside STEM education in order to support teachers and students in participating effectively in this significant educational trend. The researcher further recommends that universities and educational institutions carry out additional scientific studies with the goal of educating mathematics teachers about the value of incorporating STEM techniques into the classroom. Such recommendations play significant roles in improving the quality of mathematics instruction and learning and obtaining highly qualified mathematics teachers who are aware of the most recent educational and teaching trends.

7. Conclusion

It appears as though there has been a growing demand for mathematics teachers to provide instruction that encourages students to acquire 21st century learning skills. STEM disciplines especially mathematics offer excellent environments for helping students develop 21st century learning skills. Nevertheless, just as mathematics teachers need to obtain a thorough understanding of their field, they also need to consider STEM activities in their classrooms to assist their students in developing 21st century learning skills successfully and proficiently. According to the findings of the current study, the participating teachers applied STEM practices moderately in their classrooms in the three domains (lesson evaluation, lesson implementation and lesson planning) respectively. Moreover, the findings showed that there are statistically significant differences between the middle school mathematics teachers and supervisors in favor of the teachers regarding the degree of implementing STEM practices. Recommendations of the current study include dedicating sufficient funds for STEM education, creating creative STEM websites and labs, obtaining access to STEM resources and materials and preparing mathematics teachers to apply STEM practices in their classrooms. The current study also recommends that universities and educational institutions administer scientific studies and educational projects aimed at raising the awareness of mathematics teachers with respect to the significance of employing STEM practices in the teaching process.

8. Limitations

Several limitations exist for this study. Perhaps one of the primary limitations is that the scope of the current investigation was restricted to examining the degree of application of middle school mathematics teachers to STEM practices as recent effective trends in mathematics education. Furthermore, although this study develops generalizations across middle school mathematics teachers, the sample represents mathematics teachers as well as educational supervisors of mathematics for the middle school level in Al-Ahsa Governorate. This study was conducted during the academic year 1442-1443 AH.

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