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Research Article

The Effectiveness of Learning Mathematics according to the STEM Approach in Developing the Mathematical Proficiency of Second Graders of the Intermediate School

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This study explored the effectiveness of learning mathematics according to the STEM approach in developing mathematical proficiency with its five components (conceptual understanding, procedural fluency, strategic competence, adaptive reasoning, and productive disposition) in some mathematical concepts among second graders of intermediate school. The quasi-experimental method with the experimental and control group design was used. The participants were 40 second graders of the intermediate school in the second semester of the school year 2021-22. The experimental group ($N = 20$) was taught according to the STEM approach, while the control group ($N = 20$) was taught according to the conventional approach. Data were collected by a researcher-developed mathematical proficiency test measuring conceptual understanding, procedural fluency, strategic competence, adaptive reasoning, and productive disposition. Results of the t-test revealed significant differences in mathematical proficiency between the post-test mean scores for the experimental and control groups in favor of the experimental group. Implications drawn from the results are offered.

1. Introduction

The twenty-first century is known as the smarter century or the digital century because of its tremendous technological developments. Thus, there is a need for an innovative workforce that meets the requirements of the labor market. Concurring with the concept of work-based education, there is a need to integrate and develop students' skills in mathematics, technology, engineering, and science. Given the importance of mathematics in all areas of daily life, it is important to develop students' mathematical skills to maximize the effectiveness of teaching and learning. In the current context, education is required to focus on the new role that information, technology, and learning play to achieve good economic performance. It is also required to focus on managing, generating, funding, transferring, and investing knowledge. Focus on such aspects guarantees that educational outcomes are compatible with the requirements of the knowledge economy [1, 2].

Here emerges the challenge of innovation and the need to select brilliant learners in all fields of science, technology, engineering, arts, and mathematics to develop and provide effective solutions to global challenges [3]. This is in line with the recommendation of the World Innovation Summit for Education [4] that enhancement of skills in mathematics, science, technology, and engineering is crucial to building an innovative, diverse, and competitive workforce. Mathematical proficiency shapes the ways of ensuring successful learning of mathematics, as it includes aspects of mathematical expertise, competence, and knowledge as confirmed by several studies [5–8].

The STEM approach has many advantages in education, the most important of which is that it develops students' scientific and technological skills through learning based on real activities and experiences. It fosters their creative thinking by employing concepts and principles of science, technology, engineering, and mathematics. Furthermore, it "encourages problem-solving, critical thinking, inquiry-based learning, and natural experimentation with students" [9].

Learning mathematics according to the STEM approach contributes to the achievement of the best possible educational outcomes following educational innovations in teaching and learning mathematics by aligning with McGraw-Hill Solutions [10]. Literature stressed that McGraw-Hill Solutions have been designed to enhance the mathematical proficiency of all students at all levels [5, 6, 11]. The STEM approach also contributes to qualifying students to meet the aspirations of the labor market in the era of the Fourth Industrial Revolution through the integrative learning of science, technology, engineering, and mathematics.

2. Research Problem

There is a dearth of research exploring the effectiveness of learning mathematics according to the STEM approach in developing the mathematical proficiency of second graders of the intermediate school as confirmed by a survey of the available databases incorporating research in mathematics education. The mathematics of the second grade of the intermediate school is an indicator of improved achievement in the Trends in International Mathematics and Science Study Project (TIMMS) based on the report of the International Association for the Evaluation of Educational Achievement in the last three sessions, the last of which was in 2019 [12, 13]. The teaching and learning of mathematics in Saudi schools need to be improved by employing creative methods in light of the 2030 Vision. Accordingly, this study aimed to explore the effectiveness of learning mathematics according to the STEM approach in developing mathematical proficiency with its five components (conceptual understanding, procedural fluency, strategic competence, adaptive reasoning, and productive disposition) in some mathematical concepts among second graders of the intermediate school. More specifically, the study addressed the following main question. "What is the effectiveness of learning mathematics according to the STEM approach in developing the mathematical proficiency of the second graders of the intermediate school?"

3. Research Significance

This research is concerned with the following:

(1) Providing an attractive mathematics learning environment that increases students' positivity and participation in the educational situation through the use of the STEM approach.

(2) Creating an interactive mathematics culture that incorporates other sciences and real life.

(3) Qualifying national cadres with knowledge, expertise, and competence to contribute to national development programs and plans.

(4) Offering recommendations and suggestions for further research related to the research topic.

4. Definition of Terms

4.1. The STEM Approach. STEM is an interdisciplinary problem-solving-based approach to teaching and learning that integrates science, technology, engineering, and mathematics [14]. Operationally defined, it refers to creating a creative educational environment that helps students enjoy the integration of mathematics education with science, technology, and engineering. Thus defined, STEM is in drastic contradiction with the conventional view of mathematics as a discrete discipline.

4.2. Mathematical Proficiency. Mathematical proficiency is one of the outcomes of learning mathematics and it encompasses five components [15]. It includes all aspects of mathematical expertise, competence, and knowledge. It is "the successful learning of mathematics" [6]. Operationally defined, it refers to the scores the students would attain in the mathematical proficiency test with its five components: conceptual understanding, procedural fluency, strategic competence, adaptive reasoning, and productive disposition.

5. Review of Literature

5.1. The STEM Approach. The STEM approach has gained wide acclaim in the twenty-first century, as it is concerned with the integration of mathematics teaching with science, technology, and engineering, in contrast with the traditional view where mathematics is dealt with as a discrete discipline. This integration helps students to understand the natural world through integrative scientific knowledge, using technology, and applying mathematical, scientific, and engineering principles.

STEM is one of the promising approaches to teaching and learning mathematics. Schools and programs applying the STEM approach teach students mathematics, technology, engineering, and science integratively by focusing on realistic problem-solving, which requires students to employ their knowledge, expertise, and skills by integrating mathematics, science, and technology. In such a context, the scientific method of thinking is used and concepts of mathematics, science, technology, and engineering are linked with life outside school and the labor market [16]. Bybee [17] suggests that this approach contributes to increasing students' understanding of how things work and that it develops their skills in using technology by training them in problem-solving and teamwork.

The STEM approach integrates the following four branches of knowledge.

Scientific knowledge (S) consists of three dimensions: (1) knowledge of basic facts, principles, concepts, theories, and laws in the field of science, (2) the ability to associate and link those ideas, and (3) processes, practices, and methods of thinking that develop knowledge about the natural world and realistic problem-solving [14].

Technological knowledge (T) refers to the ability to understand, use, manage, and evaluate the technology. Students need to develop an understanding of how to use technology and possess the necessary skills to see how it modifies the natural world to meet human needs and desires [18].

Engineering knowledge (*E)* refers to the ability to achieve goals and solve problems by applying the engineering design process. It is an approach and an organized method for designing processes, objects, and systems to meet human needs and requirements. With this knowledge, students become able to apply engineering principles, processes, and practices to new situations. Engineering knowledge also means the ability to identify and define solvable problems, generate and test new solutions, and modify the design according to several functional, ethical, economic, and aesthetic considerations to arrive at the optimal solution.

Mathematical knowledge (M) relates to the learner's ability to understand and identify the roles that mathematics plays in the world. Learners with mathematical knowledge are able to reach logical conclusions. Moreover, integrating and using mathematics help individuals to think critically and meet their needs [18].

The National Academy of Education asserts that learning according to the STEM integrative approach is one of the most important requirements for preparing the learner in the twenty-first century. It makes it possible to provide learners with quality educational and professional experiences in the four disciplines, thus qualifying them for better jobs in the future [19].

5.2. Mathematical Proficiency. Learning mathematics is of considerable benefit for the future. It is important to focus on developing students' mathematical proficiency because it includes all the outcomes of learning mathematics. Mathematical proficiency includes the skill of flexible and accurate implementation of procedures and assimilation of mathematical concepts and operations during reflective and logical thinking. It also includes formulation, representation, and solving of problems, which leads the learner to see mathematics as a useful and valuable subject and gain confidence in using it [20].

Mathematical proficiency has five components:

(1) *Conceptual understanding*, which refers to a deep understanding of how mathematics works. It allows the student to build new knowledge by making connections with previously learned knowledge. It fosters retention and fluency [21]. Conceptual understanding means the assimilation of basic mathematical ideas, concepts, generalizations, and connections that enable the student to know the content in which the mathematical idea is used [15]. Students' conceptual understanding can be displayed through the following [6].

   (i) Understanding mathematical ideas: terms, concepts, generalizations, relationships, operations, procedures, etc.
   (ii) Grasping information and procedures in a coherent manner, not as discrete information.
   (iii) Knowing the importance of the mathematical idea, whether in mathematics or other theoretical or applied sciences.
   (iv) Knowing the various connections among mathematical ideas.
   (v) Representing mathematical situations with graphs, figures, or any other mathematical representations.
   (vi) Learning basic mathematical concepts and identifying common patterns.
   (vii) Reconstructing ideas and methods to solve mathematical problems and situations and producing new knowledge.

(2) *Procedural fluency* which means being accurate and competent at using algorithms in computations based on a good understanding of numerical properties and relationships. Some of these are performed mentally, while others are implemented with paper and pencil to facilitate thinking processes [22]. Procedural fluency can be displayed through the following [6].

   (i) Writing mental procedures and methods.
   (ii) Using important algorithms to test the validity of concepts.
   (iii) Having highly organized, pattern-filled, and predictable mathematics.
   (iv) Completing routine tasks efficiently.

(3) *Strategic competence* which refers to the ability to interpret and formulate mathematical problems, along with the ability to represent and solve them, i.e., "mastery of problem-solving strategies." Strategic competence can be developed through frequent exposure to mathematical problems that reflect real-world situations and that require students to interpret a question, distinguish what is required from irrelevant information, and represent the problem mathematically [21]. Students can display strategic competence through the following [6].

   (i) Finding problems that are similar in formulation and solution.
   (ii) Representing problems mathematically.
   (iii) Avoiding complex data and numbers.
   (iv) Generating models from mathematical questions.

   Solving mathematical problems requires combining conceptual understanding, procedural fluency, and strategic competence [21].

(4) *Adaptive reasoning*, which relates to the ability to think logically about the relationships among ideas and situations [6]. It is a means of convincing others of mathematical ideas and solutions to problems.

Students can show adaptive reasoning through the following [6].

(i) Thinking logically about the relationships among concepts and situations.
(ii) Providing informal explanations and justifications.
(iii) Intuition and inductive reasoning.
(iv) Basing task completion on adaptive reasoning.

(5) *Productive disposition*, which is one of the most important motivators for students' learning. It makes students convinced that they can learn and appreciate the great value of what they learn [6]. Students can show productive desire through having the following beliefs [6].

(i) Mathematics can be understood.
(ii) with diligent effort, mathematics can be learned and used.

5.3. Previous Studies. The STEM approach has received considerable research interest within the interdisciplinary movement that has combined science, technology, engineering, and mathematics. Several studies [18, 19, 23–26] recommended designing and implementing curricula according to the STEM approach. Hashem [27] reported the effectiveness of using cloud computing applications based on the STEM cognitive integration approach in developing the life skills related to learning mathematics among intermediate school students. Based on the results, the researcher recommended employing many cloud computing applications during teaching to make mathematical knowledge more enjoyable and interesting. The researcher also recommended including activities and applications related to the lives of students and the environment around them in mathematics lessons in the intermediate school.

Al-Ghamdi [28] evaluated the teaching practices of elementary school mathematics teachers according to the criteria of the STEM approach by building teaching standards for mathematics in light of the STEM approach. The descriptive analytical method was used. The sample consisted of 25 teachers. A list of teaching standards was built according to the STEM approach. The study instrument was an observation card consisting of 30 items measuring the target teaching practices. The results indicated that the teaching practices of elementary school mathematics teachers according to the STEM approach were medium in the areas of lesson planning, evaluation, and teaching strategies. The researcher recommended that mathematics teachers be trained on teaching strategies aligning with the STEM approach.

Several studies have also shed light on mathematical proficiency with its five components of conceptual understanding, procedural fluency, strategic competence, adaptive reasoning, and productive intention. The research identified many classroom practices that can enhance students' mathematical proficiency and the role of the educational community in this respect [5, 29]. Al-Ruwaithi and Al-Mohammadi [30] documented the effectiveness of the STEM approach in developing the mathematical proficiency of Saudi elementary school students. Based on the results, the researchers recommended updating mathematics curricula in light of the STEM approach.

Al-Salmi [31] also reported the effectiveness of the STEM approach in developing conceptual understanding as one of the components of mathematical proficiency in mathematics among first-year secondary school students in Jeddah. Al-Sayed [8] also recommended researching the STEM approach and found the SCAMPER strategy (mental brainstorming of mathematical ideas) effective in developing the mathematical proficiency of Prince Sattam Bin Abdulaziz University students.

6. Research Hypothesis

"There would be statistically significant differences between the post-test mean scores of the experimental and control groups in mathematical proficiency in favor of the experimental group."

7. Method

The quasi-experimental method with the experimental and control group design was used. Furthermore, the descriptive analytical approach was used in surveying the literature and previous studies. The experimental group was taught mathematics according to the STEM approach, while the control group was taught according to the conventional method that did not support the interdisciplinary approach found in STEM.

7.1. Participants. Participants included an intact class of second graders ($N = 40$) at an intermediate school in Dilam, Riyadh. The control group ($N = 20$) was taught according to the conventional method that is based on lecturing and discussion. The experimental group ($N = 20$) was taught according to the STEM approach.

7.2. The Instrument. To assess the effectiveness of the STEM-based treatment in developing students' mathematical proficiency, the researcher developed a mathematical proficiency test that covered the concepts of area and volume, equations and inequalities, linear functions, statistics, and probabilities. The test was constructed based on a literature review to identify (a) the components and skills comprising mathematical proficiency and (2) the performance indicators that operationally signify the achievement of skills. The identified indicators were then translated into questions. The test items were in the form of situations and problems that required a good understanding of the situation, expressing the steps of the solution in proper mathematical jargon and connecting concepts to real life. Test situations also required adaptive reasoning, strategic competence, and procedural fluency.

When writing the test items, the researcher made sure that (a) items reflected the nature of their respective dimensions of mathematical proficiency, (b) the wording of

Table 1: The t-test for the difference between the upper and the lower groups.

Group	N	M	df	t-value	Sig.
The upper group	16	3.84	30	9.50	0.000
The lower group	16	0.78			

Table 2: Specifications of the mathematical proficiency test.

Dimension	Question numbers	No. of items under dimensions of mathematical proficiency	%
Procedural fluency	1, 4, 9, 10	4	19
Strategic competence	1, 4, 5, 6, 10	5	23.8
Conceptual understanding	2, 6, 8	3	14.4
Adaptive reasoning	2, 3, 5, 7, 8	5	23.8
Productive disposition	3, 4, 7, 9	4	19
Total	10	21	100

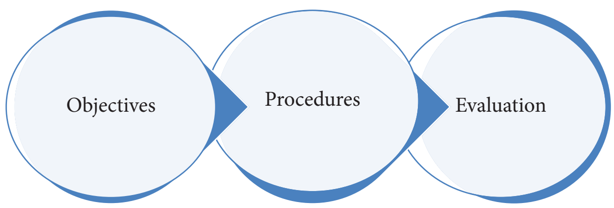

Figure 1: Steps of the STEM proposal.

the items was clear and accurate, and (c) adequate items in each dimension were formulated in anticipation that some items might be deleted after arbitration and/or the pilot study of the test. The preliminary version of the test consisted of 21 items included under 10 main questions covering all components of mathematical proficiency. Each question was allocated scores based on the steps of the solution and the levels of mathematical proficiency. The maximum score a student could get on the test was 22.

The preliminary version of the test was content validated by a jury of five mathematics education specialists. They judged the wording of the questions based on a 3-point scale (clear, somehow clear, and unclear) and the inclusion of questions under proficiency components based on another 3-point scale (related, somehow related, and unrelated). An agreement of 75% was set as a criterion to accept the jury members' viewpoints. This resulted in the rewording of some questions.

The test was then pilot-tested on 45 students from outside the main study sample to establish its discriminant validity. The test was found to discriminate between the upper and lower groups as shown in Table 1. As to reliability, the test yielded an alpha estimate of 0.89, which indicated that it was quite reliable.

The following table (Table 2) shows the specifications of the test after its validation.

7.3. The Proposed STEM-Based Treatment. The treatment lasted for a whole semester (the second semester of the academic year 2021/22). The control group was taught according to the conventional method that is based on lecturing and discussion. The experimental group was taught according to the STEM approach. The proposed STEM-based treatment was identified based on a survey of relevant literature [6, 24, 32–35]. The proposal (Figure 1) that used a set of situations, activities, and projects was characterized by

(i) Students' positive participation.
(ii) Diversification of learning.
(iii) Consolidating mathematical experiences by linking them to life and the disciplines of science, technology, and engineering.
(iv) Developing problem-solving skills, motivation, and higher-order thinking skills.

The identification of the proposed treatment and its implementation followed these steps:

(i) Determining learning outcomes.
(ii) Defining general objectives, lesson ideas, and items.
(iii) Defining activities, methods, and performance tasks based on the interdisciplinary view that integrates science, technology, engineering, and mathematics.
(iv) Teaching students according to the proposed treatment. In this stage, the STEM approach was put into practice. Students performed integrative learning tasks that entailed both individual and collaborative work. The teacher monitored students' learning, provided the required support, and when necessary made changes in the teaching plan.

8. Results and Discussion

To test the effectiveness of the STEM approach in developing students' mathematical proficiency, the t-test was used to identify the differences between the post-test mean scores of the experimental and control groups. Squared eta (η^2) was also used to assess the effect size of the experimental treatment. All statistical treatment was performed with the SPSS program.

The t-test for independent samples was performed on students' answers to the mathematical proficiency post-test with its five components. The following table (Table 3) presents these results.

Table 3: Differences between the two groups on the mathematical proficiency post-test.

Dimension	Exp. Group ($N = 20$)		Cont. Group ($N = 20$)		t-value	$\alpha = 0.01$	η^2	Effect size
	M	SD	M	SD				
Conceptual understanding	14.54	0.60	1.73	1.20	2.91	Sig.	0.31	High
Procedural fluency	14.49	0.63	1.72	0.87	2.89	Sig.	0.30	High
Strategic competence	14.47	0.67	1.56	0.41	3.54	Sig.	0.41	High
Adaptive reasoning	14.44	0.79	1.69	0.54	3.80	Sig.	0.41	High
Productive disposition	15.61	0.79	1.81	1.27	2.92	Sig.	0.32	High
Total	73.55	2.39	8.51	4.98	3.59	Sig.	0.41	High

It is clear from Table 3 that

(1) The post-test mean scores of the experimental group and the control group in conceptual understanding were 14.54 (SD = 0.60) and 1.73 (SD = 1.20), respectively. A statistically significant difference was found between the two groups ($t = 2.91$, $\alpha = 0.01$) in favor of the experimental group.

(2) The post-test mean scores of the experimental group and the control group in procedural fluency were 14.94 (SD = 0.63) and 1.72 (SD = .87), respectively. A statistically significant difference was found between the two groups ($t = 2.89$, $\alpha = 0.01$) in favor of the experimental group.

(3) The post-test mean scores of the experimental group and the control group in strategic competence were 14.47 (SD = 0.67) and 1.56 (SD = .41), respectively. A statistically significant difference was found between the two groups ($t = 3.54$, $\alpha = 0.01$) in favor of the experimental group.

(4) The post-test mean scores of the experimental group and the control group in adaptive reasoning were 14.44 (SD = 0.79) and 1.69 (SD = .54), respectively. A statistically significant difference was found between the two groups ($t = 3.80$, $\alpha = 0.01$) in favor of the experimental group.

(5) The post-test mean scores of the experimental group and the control group in productive disposition were 15.61 (SD = 0.79) and 1.81 (SD = 1.27), respectively. A statistically significant difference was found between the two groups ($t = 2.92$, $\alpha = 0.01$) in favor of the experimental group.

(6) The post-test mean scores of the experimental group and the control group in total mathematical proficiency were 73.55 (SD = 2.39) and 8.51 (SD = 4.98), respectively. A statistically significant difference was found between the two groups ($t = 3.59$, $\alpha = 0.01$) in favor of the experimental group.

It is clear from Table 3 that squared eta (η^2) for the effect sizes of the individual components of mathematical proficiency and mathematical proficiency as a whole was high. They ranged between 0.30 and 0.41.

According to the California Department of Education, STEM is the incorporation of the four disciplines of science, technology, engineering, and mathematics in an interdisciplinary approach and implemented in a meaningful context and problem-based learning. STEM is also a process of critical thinking ability (CTA), assessment, and cooperation where participants incorporate procedures and notions in authentic environments. According to research done by Hidayah and Rohaida [36], learners may explore occurrences, form conclusions, and develop scientific abilities via practice. Furthermore, Irma et al. [37] demonstrated that engineering is a career in which knowledge of science and mathematics is acquired via research, investigations, and practices put into use while thinking about the formulation of methods to combine materials and natural forces to suit human requirements.

According to [38, 39], STEM education has the capacity to develop both the learners' interest in the subject matter as well as their ability to engage in higher-order thinking. The more substantial effect of participants' higher-order thinking skills (HOTSs) and interest may be due to the nature of the learning methodologies and tools of STEM education, which are based on eastern cultures and underscore hands-on operations [40]. Actual problems and the ability to find solutions to those problems are two hallmarks of STEM education, both of which have the potential to significantly improve learners' HOTS. The development of higher-order thinking skills, such as the ability to solve problems, think critically, and think creatively, is one of the primary goals of STEM education [41, 42]. As a result, HOTS is an invaluable resource for learners in Asia who are attempting to compete on a global scale and succeed in the 4.0 industrial revolution.

The findings of prior studies are consistent with the findings of the current study, which indicates that the STEM learning strategy increases participants' scientific attitudes and conceptual knowledge. This occurs because STEM learning requires learners to combine the four components of the STEM approach to education. Four elements of the STEM method may enable learners to improve their cognitive abilities. In addition, the STEM learning method may inspire students to comprehend and manage natural occurrences, employ technology, create or organize, and analyze answers derived from data and calculations.

One of the key reasons for these findings is that STEM forecasts academic success beyond one's abilities or past advancement since confident people are motivated to excel. Learners who have strong scientific self-efficacy set more difficult objectives and work harder to achieve them than learners who have poor science self-efficacy. More significantly, in STEM education, learners address real-

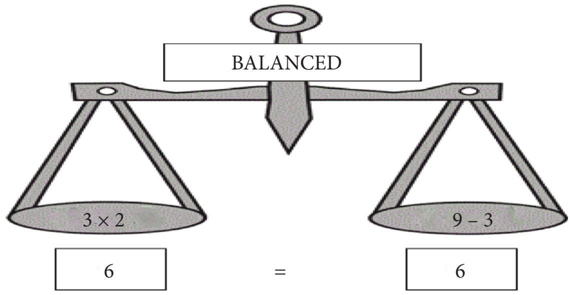

Figure 2: Students' design of the arithmetic balance in equations.

world issues based on their prior knowledge. This increases learners' motivation, which results in more ideas being learned and comprehended. Furthermore, motivation may spur the development of learners' aspirations, enthusiasm for future careers, and curiosity in mathematics and science. STEM approaches may improve students' critical thinking abilities, which has a significant impact on decision-making and issue solving. STEM education has the ability to promote 21st century abilities such as teamwork, enthusiasm, inventiveness, and critical thinking [43]. With exercises in teamwork, problem-solving, critical thinking, inventiveness, and invention, STEM education may equip learners to confront global challenges [44]. It is obvious that a STEM strategy may successfully improve learners' CTA.

Multiple modalities are considered one noteworthy technique for teaching STEM topics that should be regarded as a means of enabling EFL learners to take part in language-demanding programs such as developing arguments and reasoning from evidence. When evaluating and interpreting data in the mathematics classroom, students utilize graphs and tables as instruments. As EFL/ESL learners gain scientific knowledge, they progressively use different modalities, such as diagrams and symbols, during teaching. Pertinently, students understand how to convey the growing intricacy of their thoughts through a variety of formats. Participants get a better knowledge of when to utilize graphs, how tables portray patterns, and how arrows are employed to express connections. This is especially important in the present environment of expanding Internet delivery. Direct instruction in a classroom is more useful to EFL/ESL students because they can converse with their instructor, observe facial gestures, and pose questions as they occur. Learners may interact with their classmates in classroom learning settings. This also gives a learning opportunity. It is apparent, therefore, that one of the most pressing issues for individuals studying English as a second language in the face of COVID-19 limits is the lack of face-to-face learning possibilities in all educational contexts. If the current format of more online courses and engagement continues beyond COVID-19, most of the personal interaction and connections will be eliminated.

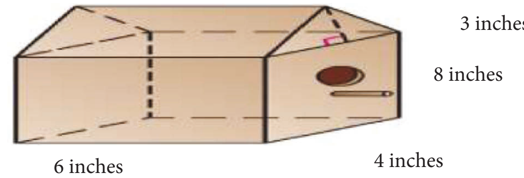

Figure 3: A cage for small birds using GeoGebra program.

9. Conclusion

The results of the current research revealed that the STEM approach resulted in significant improvements in total mathematical proficiency and its five components of conceptual understanding, procedural fluency, strategic competence, adaptive reasoning, and productive disposition. These improvements can be attributed to the nature of the tasks performed by the experimental group that integrated science, technology, engineering, and mathematics.

Figure 2 shows an example of the students' participation photos.

Another example is designing a cage for small birds with different dimensions by using the GeoGebra program and then calculating the size which is shown in Figure 3.

The STEM-based tasks that students completed throughout the treatment encouraged them to use unconventional learning modes, e.g., self-learning, cooperative learning, and discovery learning. The tasks and activities also fostered collaborative work and connection with real-world situations. The mathematical tasks that were designed according to the STEM approach challenged students and urged them to use higher-order thinking and problem-solving skills. It was also observed that students worked on STEM-based tasks and activities enthusiastically, which fostered their productive disposition. This finding concurs with previous studies [5, 8, 18, 19, 25–31].

10. Implications and Recommendations

According to the findings of this research, to successfully apply STEM teaching and learning inside a classroom, many variables need to be taken into consideration. To begin, instructors are free to mix STEM courses with whatever teaching style or learning model they think appropriate. For example, educators might integrate the teaching of STEM subjects with either a learning model or a method based on project-based learning. The mixture would provide a clear and powerful direction for a teacher to follow to accomplish the objective of the lesson. Incorporating aspects of the local culture into STEM education is yet another approach. Participation of this kind is fundamental to teaching that is culturally relevant and necessary to the academic achievement of students. Local culture may be included in a school's curriculum in several different ways, including the primary lesson content, the enrichment materials, the method of instruction and learning, and even the usage of locally adapted languages and property names. In conclusion, when it comes to applying for STEM courses, it is essential to first determine the amount of time that will be required and then devote an adequate amount of time to the application process. According to the findings of the research, giving learners an increased amount of time that may be distributed over two or more class times would help them improve their academic learning accomplishment and higher-order thinking skills [45]. Consequently, these three considerations are important to maximize the impact of STEM education on students' academic results. The fact that just a small number of carefully chosen studies were included in this research raises certain concerns. The author of the paper has made a strong recommendation that researchers and educators make STEM education a continuous element of the learning process. There is yet additional research that was not found that is likewise relevant to STEM education and the efficacy of the learning outcomes for students [46, 47]. These constraints may be brought on by a variety of factors, such as the language that is employed in the title, as well as abstracts that are written in languages other than English. Because this study is more centered on the meta-analysis method, which analyzes the quantitative approach, we cannot determine whether or not the learning outcome acquired so far has anything to do with teacher attitudes and understanding of STEM education. Another limitation is that this study is more centered on the method that analyzes the quantitative approach. Also, regarding the computation of impact size on the prospective moderator factors, this present study is still restricted by the number of studies that have been conducted. According to the findings of a power analysis, the size of the sample group produced results that were not strong enough to achieve significant and considerable impacts for the variables that were being studied. To validate the analysis of the results and go on with the next phase of research, a greater number of investigations are required. In spite of this, we feel that this study is a beginning point that is comprehensive, accurate, and dependable in terms of giving up-to-date information regarding the circumstances surrounding the implementation of STEM.

Based on the results, the following recommendations are offered:

(1) Basing mathematics education on the STEM approach and similar approaches that foster the interdisciplinary nature of sciences.

(2) Providing mathematics resource centers and laboratories in all stages of general education with STEM-based learning strategies.

(3) Training mathematics teachers and supervisors on using the STEM approach and developing students' mathematical proficiency.

11. Suggestions for Further Research

(1) Replicating the current study with other samples and environments.

(2) Investigating the effect of the STEM approach on critical thinking skills and attitudes towards learning mathematics.

(3) Replicating the current study with gifted students and low achievers.

(4) Based on the findings, the discussion, and the limitations of this study, potential future research could include examining teachers' attitudes (based on their philosophy and belief) and present understanding regarding STEM education, as well as how to implement the strategy in various fields of study. This research may serve as a source of motivation for researchers to create or alter STEM teachings that originated in western nations into diverse STEM kinds and variations that are appropriate for the cultural context and geographical circumstances of each country. Furthermore, an effort to build, administer, or alter STEM-related curricula is also a viable future research possibility. This might be done in the present or the future [48, 49].

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The author declares that there are no conflicts of interest.

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