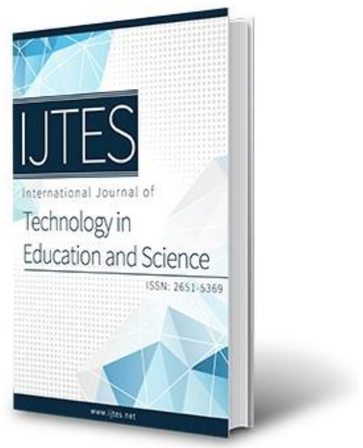

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Abstract

This study evaluated STEM education from the perspective of science, mathematics, and computer science teachers. The opinions of experienced STEM teachers were obtained and the results were analyzed in three subcategories. Phenomenological design, one of the qualitative research methods, was used for the study. The data for the study were collected from four different public middle schools in Izmir, Turkey, during the 2018-2019 school year. The qualitative data of the study was collected through a semi-structured interview with twelve middle school teachers. The professional experience of the teachers participating in the study ranged from 4 to 37 years. In addition, 6 of the teachers were female. To ensure data diversity in the study, teachers' views on STEM were collected through a 13-item questionnaire. The STEM-TSAS questionnaire used for the study had three sub-factors (teachers, school administrators and students in STEM education). The interviews with teachers revealed that STEM contributes to the development of 21st century skills in both students and teachers. In addition, many teachers indicated that school administrators were unable to provide the materials needed in the implementation of STEM education.

Introduction

The information and technological age has brought the concept of 21st century skills into the lives of societies and individuals. The 21st century skills can be divided into three categories (Wang, 2012). The first category is life and job skills. These skills include flexibility, entrepreneurial self-determination, productivity, leadership and social skills. The second category is learning and renewal skills. These skills include creativity, innovation, critical thinking, problem solving, communication, and collaboration. The last category is information, media, and technology skills. These skills include media, information, and communication technology literacy.

In the 21st century, it is easy and quick for individuals to access information. The only important thing is to find the right information. Individuals need new teaching methods and approaches to learn the necessary information (Akaygun & Aslan-Tutak, 2016; Yaki, Saat, Sathasivam, & Zulnaidi, 2019). One of these new teaching approaches is STEM education. The main practitioner of STEM education is teachers (McDonald, 2016; Wang, 2012).

STEM was first introduced by the American National Science Foundation (NSF) in the early 1990s (Bybee, 2011).

STEM is the acronym for Science, Technology, Engineering and Mathematics (Bybee, 2010). Dugger (2010) stated that STEM education is a multidisciplinary approach. Zollman (2012) divided STEM into three factors. The first factor includes social, economic, and personal needs. The second factor includes cognitive, affective, and psychomotor areas of learning. The last factor includes scientific, technical, engineering and mathematical skills. In general, STEM can be defined as the formulation and implementation of a joint solution strategy by disciplines close to each other to solve the problems encountered in daily life (Hasanah, 2020; Li, Wang, Xiao, & Froyd, 2020; Siregar, Rosli, Maat, & Capraro, 2020).

In STEM, the role of teachers in developing students' cognitive, affective and psychomotor skills and enhancing 21st century skills (problem solving, leadership, critical thinking, communication, etc.) is very important. When STEM is applied at all levels of education, teachers must first overcome the problems (curriculum, project support, time, materials needed, etc.) they encounter. They must believe that they can overcome the problems, show high performance, and renew themselves in every way (Shernoff, Sinha, Bressler, & Ginsburg, 2017).

A qualified curriculum is necessary for STEM. Many researchers (Eroglu & Bektas, 2016; Haciomeroglu, 2018) emphasize that creating a STEM-based curriculum should aim at solving problems that students may encounter in real life. In a STEM-based curriculum, students' achievements such as model design, data processing, data analysis and interpretation should be included (Wang, 2012).

Many studies have been conducted on STEM education that support the development of teachers' scientific and social skills (Cheng & So, 2020; So, Zhan, Chow, & Leung, 2018). There have also been many research papers published on various topics related to STEM education. Some of the topics can be mentioned as examples: Difficulties in implementing STEM education (Leung, 2020), teachers' experiences in STEM education (Aslan-Tutak, Akaygun, & Tezsezen, 2017; Brown & Bogiages, 2019; Eroglu & Bektas, 2016; Shernoff et al, 2017), studies on curriculum development for STEM education (Aslan-Tutak et al., 2017; Ntemngwa & Oliver, 2018), perceptions and motivations of teachers for STEM education (Akaygun & Aslan-Tutak, 2016; Haciomeroglu, 2018; Karisan, Macalalag, & Johnson, 2019; Kim & Bolger, 2017; Landicho, 2020; Margot & Kettler, 2019; Nguyen, Nguyen, & Tran, 2020), qualitative studies conducted on STEM education (Wilson, Campbell-Gulley, Anthony, Peréz, & England, 2022), the importance of technology use strategies and alternative teaching models to support the learning of the students on the STEM education (Asigigan & Samur, 2021; Wu, Cheng, & Koszalka, 2021;Yang & Baldwin, 2020).

Research on STEM education points to the positive effects on teachers' experiences, professional skills, and knowledge gains. However, apart from a few studies (Bruce-Davis, Jean Gubbins, Gilson, Villanueva, Foreman, & DaVia Rubenstein, 2014; El-Deghaidy, Mansour, Alzaghibi, & Alhammad, 2017), there is no comprehensive study on STEM education in the literature that involves teachers, school administrators, and students. Generally, studies on STEM education have examined the components of teachers, students, and school administrators as separate parameters.

This study differs from other studies by assessing the impact of the three components on STEM education as a whole. Both qualitative and quantitative data sources were used to assess the above components. It is expected that the data collected on STEM education will be informative to researchers working in the field.

Method

A phenomenological research design was used in this study. Phenomenology is a type of qualitative study that examines the phenomena we encounter in our lives but do not have detailed knowledge about or do not think much about (Cresswell & Creswell, 2017). The purpose of this study was to determine science, mathematics, and computer science teachers' knowledge and experiences about STEM education using the phenomenological design.

The necessary legal permissions were obtained from the İzmir Provincial Directorate of National Education to conduct the research. The data of the study were collected during the 2018-2019 school year in Izmir, Turkey. 12 middle school teachers in four different middle schools voluntarily participated in the study. The work experience of the middle school teachers ranged from 4 years to 37 years. The six teachers were female. One letter was coded for each teacher who participated in the study. The distribution of teachers is shown in Table 1.

Table 1. The Distributions of Teachers according to Gender and Discipline

Teacher	A	B	C	D	E	F	G	H	W	X	Y	Z
Gender	F	F	M	M	F	F	M	M	F	F	M	M
Discipline	S	S	S	S	M	M	M	M	IT	IT	IT	IT

Note: A-Z: Teacher; F: Female; M: Male; S: Science; M: Mathematics; IT: Information Technology

Data Tools

A semi-structured interview sheet was used for the research. Based on the literature (Eroglu & Bektas, 2016; Kanadli, 2019; Nowikowski, 2017; Ozbilen, 2018), an interview form with six questions was prepared. The interview sheet was presented to three academics working in the field STEM to obtain opinions. Following the expert opinions, the recommended corrections were made to the interview questions. Sub-questions were added to the 2nd and 3rd interview questions to clarify the data collected.

Each interview with teachers lasted approximately 20 minutes. To avoid loss of data during the interview, the interviews were audio and written recorded. The recorded interviews were read to the teachers and their consent was obtained. Interview data were analyzed by two academics. Common themes and codes were generated by merging the codes that were identified by the academics and had similar characteristics. The generated codes and themes were presented in the research findings.

In order to obtain a variety of data, teachers were presented with a researcher-developed 13-item questionnaire on a 5-point Likert scale at the end of the interview. The questionnaire was administered to 256 teachers to check the validity and reliability of the questionnaire before the present study. According to factor analysis, the questionnaire consisted of three sub-factors. The questionnaire was called and abbreviated as STEM-TSAS (STEM-Teacher, School Administration, and Students) based on the sub-factors. The sub-factors were teachers (T), school administrations (SA) and finally students (S). Some statistical results (explanatory and confirmatory factor analysis) of the STEM-TSAS questionnaire are presented in Appendix.

Results

The data obtained from the interviews with the teachers who participated in the study were analyzed and the results were presented as follows.

I.IQ-Can you define STEM education?

Two themes were identified for the first interview question. The themes presented in Table 2 are "instructional model" and "interdisciplinary interaction". The aim was to use the themes and codes to determine the teachers' general opinion about STEM education.

Table 2. Teachers' Opinions about STEM Education

Theme	Code
Instructional model	Problem solving Creative thinking Analytical thinking Project-based learning Cooperative learning
Interdisciplinary interaction	Application of science to everyday life Integrating science with technology Integrating science with engineering Integrating science with mathematics Integrating science with other disciplines

Many teachers defined STEM education as a model of instruction. They agreed that teaching STEM through a combination of science, technology, engineering, and mathematics fostered students' problem-solving, creative thinking, and analytical reasoning skills. They stated that science, in particular, interacts with daily life as well as many disciplines in the STEM classroom. The statements of some teachers are given below:

> A *"It is an educational approach that develops students' creative thinking skills, enables them to acquire problem-solving skills, and also improves their decision-making ability by empowering them to take responsibility."*
>
> B *"It is an educational model that improves students' analytical thinking and problem-solving skills by making knowledge from science and math courses applicable to real life."*
>
> C *"It's a system that takes subjects like science and math out of the rote learning system and shows the*

applicability of the information to real life."

E *"It is a teaching model that promotes interdisciplinary activities and strengthens analytical thinking by integrating science, mathematics, and engineering knowledge with a technology-based system."*

X *"It is a teaching model that consists of science, technology, engineering, and mathematics concepts and aims to develop students' perspectives by using interdisciplinary relationships."*

II.IQ-Have you received training on how to implement STEM education?

Three themes were identified for the second interview question. This interview question consisted of five sub-questions. The themes, listed in Table 3, were "received training", "training time", and "communication tools" on STEM training. The themes and codes were used to determine the ways in which teachers receive information about STEM education.

Table 3. The Training of Teachers about STEM Education

Theme	Code
Received Training	In-service training Distance learning Attendance at seminars and congresses
Training Time	One week One day One hour
Communication Tools	Official letter Social media Not informed

Many teachers received STEM in-service training organized by provincial and district national education directorates. Some teachers attended STEM seminars organized by some state and private universities. Teachers indicated that the duration of STEM seminars varied from one hour to one week. Many teachers felt that STEM seminars were not sufficient. They also indicated that school administrators did not provide sufficient information about the location and time of STEM educational seminars.

III.IQ-How have you implemented STEM education with your lessons?

Three themes were identified for the third interview question. This interview question included four sub-questions. The themes listed in Table 4 were "subject", "material", and "challenge." The aim was to use the themes and codes to identify the teachers' implementation processes in relation to STEM education.

Many teachers indicated that STEM was easy to implement in physics subjects. Mathematics and computer science teachers, in particular, expressed that STEM instruction was not easy to apply to mathematics and computer science subjects. From the interviews with science teachers, it was found that they generally introduced

STEM-based activities in some subjects such as simple machines, force, motion, energy and the structure of matter.

When evaluating the opinions of science teachers, the reasons they gave for using STEM-based activities in these subjects were that they were inexpensive, based on simple tools and equipment, and could be accessed by classmates. Mathematics teachers generally used examples from everyday life for the STEM-based activities. Computer science teachers also used STEM-based activities to program and model robots.

Table 4. The Implementation of STEM Education

Theme	Code
Subject	Simple machines Force and motion Energy Recycle Space and planets Structure of matter Germination Cell structures Coding Modeling
Material	Simple tools Computer Internet Software Laboratory equipment Storage space
Challenge	Provision of course materials Cognitive differences among students Lack of time Inadequate laboratory, household, and STEM education sets Lack of materials in STEM educational kits Lack of discipline in the classroom Inadequate knowledge of subjects Inadequate basic knowledge of technology Dislike of students towards STEM-based activities

Many science teachers conducted STEM-based activities in the classroom rather than in the laboratory because they did not have adequate laboratory conditions. Some teachers conducted STEM-based activities by meeting with students at school on weekends because they did not have enough time on weekdays. During the interviews with the teachers, they encountered many challenges in conducting STEM-based activities. Some of these challenges could be cited as examples (overcrowded classrooms, difficulty in obtaining teaching materials for STEM-based activities, lack of time, etc.). Some of the teachers faced difficulties in technology and engineering in STEM-based activities despite having sufficient knowledge in science and mathematics subjects.

IV.IQ-Do you think teaching on STEM is important for your field?

The aim was to use the themes and codes in this interview question to determine the importance of STEM education in relation to teachers' branches. Teachers' opinions were collected under one theme "Teachers" as seen in Table 5.

Table 5. The Importance of STEM Education in Relation to the Fields of Teachers

Theme	Code
Teacher	Project development
	Development of problem solving and communication skills
	Development of creativity and cooperative learning
	Increasing motivation
	Teaching the concretization and visualization of topics
	Enabling collaboration with other disciplines
	Pursuing scientific and technological innovation

Many teachers indicated that STEM education was important to their subject area. STEM-based activities contributed positively to teachers' problem-solving skills, critical thinking skills, communication skills, and professional experiences. The following are the statements of some teachers.

> A *"It adds to our professional experience, and we can feel the happiness of the profession much better because students will participate more in the process. We may have to keep renewing ourselves as the performance level of the class increases."*
>
> C *"Yes, I think if we take this approach, we contribute to our professional development by doing research, solving problems, and sharing ideas with our colleagues in other disciplines."*
>
> D *"Since many students cannot learn science subjects by doing and experiencing, they have difficulty grasping the simplest physical rule. In this approach, students who need to think together in physics, math, technology, and engineering can uncover new ideas."*
>
> G *"It is definitely important because it also has a more effective and time-saving function in presenting some gains. It has the effect of broadening the horizon of thinking."*
>
> W *"I think it's very effective for teachers to increase their knowledge and skills and get up to speed."*
>
> X *"It provides the opportunity to collaborate with other disciplines. It allows them to use technology more effectively. It allows them to gain knowledge outside of their discipline. It requires working outside of work hours."*
>
> Y *"I think STEM teaching approach to information technologies is important. I think that especially in programming subjects, joint study with mathematics will be productive."*

V.IQ-What expectations do you have for school administrators in implementing STEM education?

The interview question aimed to determine teachers' expectations of school administrators in implementing STEM education. Teachers' opinions were collected under one theme of "expectations" as seen in Table 6.

Table 6. Expectations of the Teachers to the School Administration

Theme	Code
Expectation	Provision of professional support
	Establish a counseling centre for STEM education
	Sufficient number of STEM educational kits
	Reducing the number of students in classes
	Conducting examinations to evaluate STEM instruction
	Preparation of flexible course schedules
	Establishment of cooperation between school, industry and university
	Financial support for STEM-based projects
	Preparing the curriculum for STEM education
	Improving classroom and laboratory conditions

School administrators' expectations for science teachers to do more STEM-based activities were higher than the expectations of other teachers. The most important expectation of science teachers is fully equipped laboratories. Mathematics and computer science teachers stated that the curriculum needs to be reduced in order to implement STEM-based activities more efficiently and beneficially.

Many teachers expressed that school administrators should reward student prepared projects and encourage students in STEM-based activities. Many teachers expected the school administration to organize in-service trainings on STEM education and develop projects between school, industry and college. The statements of some teachers are listed below:

> B *"In my opinion, teachers need to be trained in the STEM-teaching approach, the curriculum needs to be updated in this direction, teaching environments in schools need to be adapted to the STEM -teaching approach, and teaching materials need to be provided."*
>
> D *"STEM-training should be provided for teachers. Teachers should be taught about the practices in the school. The physical conditions of the school should be improved, the number of students in the classroom should be reduced, technology classes and laboratories should be established."*
>
> H *"School administrators should be able to manage the process and provide necessary and sufficient conditions for teachers and students."*
>
> Z *"School administrators should provide teachers with flexible programs, in-service training, and the*

necessary work environment."

VI.IQ-What suggestions do you have for teachers who want to do STEM education?

The sixth interview question was designed to identify suggestions for teachers who will implement STEM lessons. Teachers' opinions were collected under a "suggestions" theme, as shown in Table 7.

Table 7. Teachers' Suggestions for STEM Teaching

Theme	Code
Suggestion	Implement STEM education at all levels
	Monitoring innovations in science, technology and engineering
	Use of new educational methods and strategies
	Use of measurement and evaluation techniques
	Use of technology
	Participation in-service training, congresses, etc.

Many teachers have made some suggestions for teachers to STEM implement. First and foremost, teachers should be trained in STEM education, receive training in project development, keep abreast of developments in science, technology and engineering, and regularly attend in-service training and seminars on STEM education.

The Findings of STEM-TSAS Questionnaire

At the end of the interviews with the teachers, they were asked to complete a 13-item STEM-TSAS questionnaire. The questionnaire was used to ensure consistency in the responses to the interview questions. With the help of the questionnaire, the teachers' responses were analyzed into three sub-factors. When the results of the sub-factors of the questionnaire were discussed in relation to teachers in STEM education, school administrators in STEM education and students in STEM education, the results of the questionnaire were similar to the findings from the interview questions.

The frequency distributions of the questionnaire are shown in Table 8:

- The frequency distribution of the first factor shows that STEM education has improved creativity, problem solving skills and critical thinking skills of many teachers.
- The frequency distribution of the second factor shows that teachers' expectations of school administrators were lower on some issues (flexible working hours, collaboration between school, industry and university on STEM-based projects, material support for the laboratory, etc.).
- Finally, the frequency distribution of the third factor shows that STEM education improves students' self-confidence and communication skills.

Table 8. The Frequency Distributions of the Items according to the Sub-factors of the Questionnaire

Items			Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
T	1	STEM education enhances teacher creativity.	75%	25%			
	2	STEM education improves teachers' problem-solving skills.	92%	8%			
	3	STEM education develops teachers' critical thinking skills.	75%	25%			
	4	STEM education improves teachers' ability to collaborate with teachers in other disciplines.	92%	8%			
	5	STEM education increases teacher motivation.	83%	17%			
SA	6	School administration provides teachers with a flexible work schedule.				25%	75%
	7	School administration provides collaboration between school, industry and university for project work of teachers and students.				8%	92%
	8	School administration provides in-service training opportunities to teachers for their professional development.				8%	92%
	9	School administration supports project work of teachers and students.				17%	83%
	10	School administration provides teachers with necessary material support for their laboratory work.				17%	83%
S	11	STEM education improves students' ability to collaborate with their classmates.	83%	17%			
	12	STEM education increases students' self-confidence.	75%	25%			
	13	STEM education improves students' communication skills.	92%	8%			

Discussion and Conclusion

The results of the investigation according to the interview questions are discussed below in each case. Many teachers were able to define STEM education because they had training and experience with STEM education. In the interview with teachers, they indicated that STEM education was a multidisciplinary approach.

In general, many teachers received in-service training on STEM. Some of the teachers received their STEM training in workshops organized by public and private universities. They stated that the training organized by

STEM was not sufficient in time and efficient. Many studies in the literature come to similar conclusions (Aslan-Tutak et al., 2017; Margot & Kettler, 2019; Ozbilen, 2018; Siew, Amir, & Chong, 2015). During the interviews, many teachers expressed that the school administration does not give sufficient explanations about the seminars and in-service trainings organized for STEM.

Many science teachers stated that the preparation of STEM-based activities takes a lot of time. Therefore, it was difficult to use STEM-based activities in all subjects. Many teachers needed basic requirements for implementing STEM-based activities. These included the materials needed to prepare and implement STEM-based activities, a suitable laboratory environment, a flexible curriculum, etc. Previous studies (Aslan & Bektas, 2019; Landicho, 2020; Margot & Kettler, 2019; Ozbilen, 2018) reported that teachers faced the same challenges in implementing STEM lessons.

Science, math and computer science teachers said that STEM was important to their subject areas. They felt great enthusiasm in preparing and implementing STEM-based activities, and this enthusiasm had a positive impact on students. According to the research findings, many science teachers felt that STEM was more appropriate for science teaching because they conducted more STEM-based activities than other subject teachers. Mathematics and computer science teachers used STEM-based activities. Especially, many mathematics teachers conducted STEM-based activities by giving examples from daily life. Computer science teachers conducted STEM-based activities by modeling and coding. Many teachers maintained contact with science, mathematics, computer science, and other teachers while conducting STEM-based activities. Many studies in the literature reached similar conclusions (Akaygun & Aslan-Tutak; 2016; Asigigan & Samur, 2021; Aslan-Tutak et al, 2017; Aslan & Bektas, 2019; Li et al, 2020; Margot & Kettler, 2019; Ozbilen, 2018; Yildirim, 2016). The studies have shown that STEM education is important for teachers' own fields.

Many teachers indicated that basic requirements such as providing a suitable physical environment for STEM-based activities and providing the necessary material support should be met by the school administration. They also expressed that if the material support for STEM-based activities could not be provided, the activities would remain unfinished and they could not move to the next phase. They were very tired and could not perform their duties because the preparation and implementation of STEM-based activities took too much time. For this reason, they needed a flexible study program to conduct their STEM-based activities in a useful way. Many studies came to similar conclusions (Aslan & Bektas, 2019; El-Deghaidy et al, 2017; Estapa & Tank, 2017; Landicho, 2020; Margot & Kettler, 2019; Ozbilen 2018; Shernoff et al, 2017). The researchers found that school administrators should meet teachers' expectations to achieve desired outcomes on all components of STEM education.

Many teachers stressed the importance of preparing to implement STEM-based activities. They also recommended that new teachers attend in-service trainings held by experts to learn the basics of technology education and use technology in their teaching. Many studies came to similar conclusions (El-Deghaidy et al., 2017; Landicho, 2020; Margot & Kettler, 2019).

The findings of the study show that STEM education has positive effects on both students' 21st century skills and teachers' professional development. The most important role and responsibility in the implementation of STEM education falls on school administrators. This is because school administrators are the ones who make the decisions about the implementation of STEM education. For this reason, school administration can provide in-service training to teachers on STEM and support them in this regard. The school administration can announce academic events such as seminars, conferences and congresses on STEM education. For this purpose, the school administration can make announcements about the in-service trainings to be organized through the teachers' email addresses, social media accounts and bulletin boards. To achieve the desired success in STEM education, school administrators should support STEM-based projects, teachers should be open to innovation in their professional development, and students should be willing to learn.

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References

Akaygun, S., & Aslan-Tutak, F. (2016). STEM images revealing STEM conceptions of pre-service chemistry and mathematics teachers. *International Journal of Education in Mathematics, Science and Technology, 4*(1), 56-71. DOI:10.18404/ijemst.44833

Asigigan, S., I., & Samur, Y. (2021). The effect of gamified STEM practices on students' intrinsic motivation, critical thinking disposition levels, and perception of problem-solving skills. *International Journal of Education in Mathematics, Science and Technology, 9*(2), 332-352. https://doi.org/10.46328/ijemst.1157

Aslan-Tutak, F., Akaygün, S., & Tezsezen, S. (2017). Collaboratively learning to teach STEM: Change in participating pre-service teachers' awareness of STEM. *Hacettepe University Journal of Education, 32*(4), 794-816. DOI:10.16986/HUJE.2017027115

Aslan, F., & Bektas, O. (2019). Determination of pre-service science teachers' views regarding STEM applications. *MM-International Journal of Educational Sciences, 3*(2), 17-50. DOI:10.46762/mamulebd.646318.

Brown, R. E., & Bogiages, C. A. (2019). Professional development through STEM integration: How early career math and science teachers respond to experiencing integrated STEM tasks. *International Journal of Science and Mathematics Education, 17*, 111-128. https://doi.org/10.1007/s10763-017- 9863-x

Bruce-Davis, M. N., Gubbins, E. J., Gilson, C. M., Villanueva, M., Foreman, J. L., & DaVia Rubenstein, L. (2014). STEM high school administrators', teachers', and students' perceptions of curricular and instructional strategies and practices. *Journal of Advanced Academics, 25*(3), 272-306. https://doi.org/10.1177/1932202X14527952

Bybee, R. W. (2010). What is STEM education. *Science, 329*, 996. DOI:10.1126/science.1194998

Bybee, R. W. (2011). Scientific and engineering practices in K-12 classrooms. *Science Teacher, 78*, 34-40.

Cheng, Y. C., & So, W. W. M. (2020). Managing STEM learning: A typology and four models of integration. *International Journal of Educational Management, 34*(6), 1063-1078. https://doi.org/10.1108/IJEM-01-2020-0035

Creswell, J. W., & Creswell, J. D. (2017). *Research Design, Qualitative, Quantitative, and Mixed Methods Approaches*. SAGE Publication.

Dugger, W. E. (2010). *Evolution of STEM in the United Stated*. 6th Biennial International Conference on Technology Education Research, Gold Coast, Queensland, Australia.

El-Deghaidy, H., Mansour, N., Alzaghibi, M., & Alhammad, K. (2017). Context of STEM integration in schools: Views from in-service science teachers. *EURASIA Journal of Mathematics Science and Technology Education, 13*(6), 2459-2484. DOI:10.12973/eurasia.2017.01235a

Eroglu, S., & Bektas, O. (2016). Ideas of science teachers took STEM education about STEM based activities. *Journal of Qualitative Research in Education, 4*(3), 43-67. https://doi.org/10.14689/issn.2148-2624.1.4c3s3m

Estapa, A. T., & Tank, K. M. (2017). Supporting integrated STEM in the elementary classroom: A professional development approach centered on an engineering design classroom. *International Journal of STEM Education, 4*(6), 1-16. https://doi.org/10.1186/s40594-017-0058-3

Haciomeroglu, G. (2018). Examining elementary pre-service teachers' science, technology, engineering, and mathematics (STEM) teaching intention. *International Online Journal of Educational Sciences, 10*(1), 183-194. https://doi.org/10.15345/iojes.2018.01.014

Hasanah, U. (2020). Key definitions of STEM education: Literature review. *Interdisciplinary Journal of Environmental and Science Education, 16*(3), 1-7. https://doi.org/10.29333/ijese/8336

Kanadli, S. (2019). A meta-summary of qualitative findings about STEM education. *International Journal of Instruction, 12*(1), 959-976. DOI:10.29333/iji.2019.12162a

Karisan, D., Macalalag, A., & Johnson, J. (2019). The effect of methods course on preservice teachers' awareness and intentions of teaching science, technology, engineering, and mathematics (STEM) subjects. *International Journal of Research in Education and Science (IJRES), 5*(1), 22-35.

Kim, D., & Bolger, M. (2017). Analysis of Korean elementary pre-service teachers' changing attitudes about integrated STEAM pedagogy through developing lesson plans. *International Journal of Science and Mathematics Education, 15,* 587-605. https://doi.org/10.1007/s10763-015-9709-3

Landicho, C. J. (2020). Research attitudes, motivations, and challenges of STEM education researchers. *International Journal of Technology in Education, 3*(1), 49-61. https://doi.org/10.46328/ijte.v3i1.21

Leung, A. (2020). Boundary crossing pedagogy in STEM education. *International Journal of STEM Education, 7*(15), 1-11. https://doi.org/10.1186/s40594-020-00212-9

Li, Y., Wang, K., Xiao, Y., & Froyd, J. E. (2020). Research and trends in STEM education: A systematic review of journal publications. *International Journal of STEM Education, 7*(11), 1-16. https://doi.org/10.1186/s40594-020-00207-6

Margot, K. C., & Kettler, T. (2019). Teachers' perceptions of STEM integration and education: A systematic literature review. *International Journal of STEM Education, 6*(2), 1-16. https://doi.org/10.1186/s40594-018-0151-2

McDonald, C. V. (2016). STEM education: A review of the contribution of the disciplines of science, technology, engineering, and mathematics. *Science Education International, 27*(4), 530-569.

Nguyen, T. P. L., Nguyen, T. H., & Tran, T. K. (2020). STEM education in secondary schools: Teachers' perspective towards sustainable development. *Sustainability, 12*, 1-16. https://doi.org/10.3390/su12218865

Nowikowski, S. H. (2017). Successful with STEM? A qualitative case study of pre-service teacher perceptions. *The Qualitative Report*, *22*(9), 2312-2333. https://doi.org/10.46743/2160-3715/2017.2893

Ntemngwa, C. & Oliver, J.S. (2018). The Implementation of Integrated Science Technology, Engineering and Mathematics (STEM) Instruction using Robotics in the Middle School Science Classroom. *International Journal of Education in Mathematics, Science and Technology (IJEMST), 6*(1), 12-40. DOI:10.18404/ijemst.380617

Ozbilen, A. G. (2018). Teacher opinions and awareness about STEM education. *Scientific Educational Studies, 2*(1), 1-21.

Shernoff, D. J., Sinha, S., Bressler, D. M., & Ginsburg, L. (2017). Assessing teacher education and professional development needs for the implemented of integrated approaches to STEM education. *International Journal of STEM Education*, *4*(13), 1-16. https://doi.org/10.1186/s40594-017-0068-1

Siew, N. M., Amir, N., & Chong, C. L. (2015). The perceptions of pre-service and in-service teachers regarding a project-based STEM approach to teaching science. *SpringerPlus*, *4*(8), 1-20. DOI:10.1186/2193-1801-4-8.

Siregar, N. C., Rosli, R., Maat, S. M., & Capraro, M. M. (2020). The effect of science, technology, engineering and mathematics (STEM) program on students' achievement in mathematics: A meta-analysis. *International Electronic Journal of Mathematics Education, 15*(1), 1-12. https://doi.org/10.29333/iejme/5885

So, W. W. M., Zhan, Y., Chow, S. C. F., & Leung, C. F. (2018). Analysis of STEM activities in primary students' science projects in an informal learning environment. *International Journal of Science and Mathematics Education*, *16*, 1003-1023. https://doi.org/10.1007/s10763-017-9828-0

Wang, H. (2012). A *New Era of Science Education: Science Teachers' Perceptions and Classroom Practices of Science, Technology, Engineering, and Mathematics (STEM) Integration.* (Unpublished doctoral dissertation), Minnesota, USA.

Wilson, C., Campbell-Gulley, B., Anthony, H. G., Peréz, M., & England, M. P. (2022). Integrated STEM education: A content analysis of three STEM education research journals. *International Journal of Technology in Education and Science, 6*(3), 388-409. https://doi.org/10.46328/ijtes.371

Wu, Y., Cheng, J., & Koszalka, T. A. (2021). Transdisciplinary approach in middle school: A case study of co-teaching practices in STEAM teams. *International Journal of Education in Mathematics, Science and Technology, 9*(1), 138-162. https://doi.org/10.46328/ijemst.1017

Yaki, A. A., Saat, R. M., Sathasivam, R. V., & Zulnaidi, H. (2019). Enhancing science achievement utilizing an integrated STEM approach. *Malaysian Journal of Learning and Instruction, 16*(1), 181-205. DOI:10.32890/MJLI2019.16.1.7319

Yang, D., & Baldwin, S. J. (2020). Using technology to support student learning in an integrated STEM learning environment. *International Journal of Technology in Education and Science, 4*(1), 1-11. https://doi.org/10.46328/ijtes.v4i1.22

Yildirim, B. (2016). An analyses and meta-synthesis of research on STEM education. *Journal of Education and Practice, 7*(34), 23-33.

Zollman, A. (2012). Learning for STEM literacy: STEM literacy for learning. *School Science and Mathematics, 112*(1), 12-19. https://doi.org/10.1111/j.1949-8594.2012.00101.x

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Appendix. Exploratory Factor Analysis Results of STEM-TSAS Questionnaire

		Factor Loadings		
	Items	T	SA	S
1	STEM education enhances teacher creativity.	.89		
2	STEM education improves teachers' problem-solving skills.	.85		
3	STEM education develops teachers' critical thinking skills.	.83		
4	STEM education improves teachers' ability to collaborate with teachers in other disciplines.	.77		
5	STEM education increases teacher motivation.	.75		
6	School administration provides teachers with a flexible work schedule.		.85	
7	School administration provides collaboration between school, industry and university for project work of teachers and students.		.83	
8	School administration provides in-service training opportunities to teachers for their professional development.		.82	
9	School administration supports project work of teachers and students.		.80	
10	School administration provides teachers with necessary material support for their laboratory work.		.79	
11	STEM education improves students' ability to collaborate with their classmates.			.85
12	STEM education increases students' self-confidence.			.83
13	STEM education improves students' communication skills.			.81
Cronbach' Alpha Values		.92	.90	.90
Eigenvalue		6.63	2.27	1.07
Explained Variance Percentage		51.08%	17.46%	8.22%

Confirmatory Factor Analysis Results of STEM-TSAS Questionnaire

Fit Index	Obtained values	Acceptable Fit	Good fit
CMIN/df	2.58	$x^2/sd \leq 5$	$x^2/sd \leq 3$
NFI	.94	$.90 \leq NFI$	$.95 \leq NFI$
TLI	.95	$.90 \leq NNFI$	$.95 \leq NNFI$
IFI	.96	$.90 \leq IFI$	$.95 \leq IFI$
CFI	.96	$.95 \leq CFI$	$.97 \leq CFI$
RMSEA	.08	$RMSEA \leq .08$	$RMSEA \leq .05$
GFI	.92	$.85 \leq GFI$	$.90 \leq GFI$
AGFI	.87	$.85 \leq AGFI$	$.90 \leq AGFI$
RMR	.03	$0 < RMR \leq .08$	$0 < RMR \leq .05$
SRMR	.04	$0 < SRMR \leq .08$	$0 < SRMR \leq .05$

Note: Chi-Square Test (CMIN/df), Normalized Index of Fit (NFI), Tucker-Lewis Index (TLI); Incremental Fit Index (IFI), Comparative Fit Index (CFI), Root Mean Square Errors of Approximation (RMSEA), Goodness of Fit Index (GFI), Adjusted Goodness of Fit Index (AGFI), Root of Mean Errors (RMR), Standardized Root of Mean Errors (SRMR)