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Teachers’ basic knowledge level of STEM education

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ABSTRACT

Science, technology, engineering, and mathematics (STEM) is a transdisciplinary approach. It aims to bring 21st-century skills to students. It is important whether teachers, who have an important place in the development of students, have knowledge that will affect students' STEM teaching. This study aims to examine the basic knowledge level of the teachers on STEM education. The descriptive method was used in the research. The study was conducted with 319 science, mathematics and information technologies teachers in the public middle schools in Turkey. “The STEM Basic Knowledge Test” was used to collect data. The first seven items of the STEM Basic Knowledge Test consist of demographic information and twenty-eight items. These items measure the basic knowledge level of STEM education. The statistical package program was used to analyze the collected data. In the study, it was determined that the STEM basic knowledge level of the teachers was 66%. Moreover, the basic knowledge level of the teachers in STEM showed a significant difference in terms of gender, teaching experience, technology use, and participation in a program such as a STEM seminar. However, there was no significant difference in terms of discipline and highest qualification of the teachers. Recommendations include encouraging teachers to participate in STEM training programs and giving courses on STEM education at the postgraduate level.

Keywords: STEM, technology, teacher, STEM basic knowledge test.

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INTRODUCTION

STEM (Science, Technology, Engineering, Mathematics) education requires students to gain 21st-century skills. These skills enable them to find solutions to problems from different perspectives, to think systematically, critically and creatively, and to offer practical suggestions (MEB, 2016). STEM aims to bring 21st-century skills to children at an early age (Acar et al., 2020). STEM covers an education that enables students to relate materials and technology to daily life uses and offers real-life applications to develop skills (Nurmaliah et al., 2021). Therefore, the basis of STEM education is the process of solving a problem that students will encounter in daily life (Wang et al., 2011).

STEM education is considered necessary for students to be able to realize their inquiry, research and problem-solving skills in daily life, to work together, and to develop their ability to create products and make inventions (MEB, 2016). For a qualified STEM education, first of all, qualified STEM teachers are needed. For the effectiveness of STEM courses, a teacher must at least know these subjects and be at the level of conceptually understanding the principles underlying rules, definitions and applications. This conceptual understanding, together with practice in the classroom, provides the formation of pedagogical content knowledge necessary for a successful STEM teacher (Eckman et al., 2016). Knowledge of STEM fields and pedagogical knowledge are considered important in STEM teaching. Teachers are required to introduce students to career discussions, role models and career-related activities during primary and middle school (Kier and Khalil, 2018). In this respect, students can be motivated to learn and increase their interest in STEM fields.

President's Council of Advisors on Science and Technology [PCAST] (2010) stated that teachers should have some qualifications both to prepare students for STEM and to encourage them. These characteristics of STEM teachers expected to have are listed below: STEM teachers;

• Understand their course topics, concepts, and procedures in-depth enough to explain them from multiple perspectives. Thus they lead students to explore.
• Can stay up to date with their developing knowledge in their fields.

• Have sufficient knowledge of STEM subjects and their relation to real life and current issues.
• Have sufficient STEM content knowledge to deal with questions from curious students and to ask thought-provoking questions to their students. They don't just say "Because it's a rule".
• Can foster student interest in STEM and inspire them to work in these domains for life.
• Encourage students to question assumptions rather than accept what is given.
• Develop students' capacity to ask research questions and find ways to solve them, rather than simply teaching students to answer predictable questions.
• Have a methodical knowledge to help classroom management and illuminate STEM issues.
• Have a deep understanding of how students approach STEM subjects.
• Notice real misconceptions and help students abandon their misconceptions based on real understanding, not memorization.
• They guide students in scientific research, design of experiments and making sense of data.
• They know how to motivate and excite students to learn about STEM subjects (PCAST, 2010).

For the effectiveness of STEM education, teachers should develop these skills and reflect them to the curriculum and students. Çorlu (2014), while listing the characteristics that STEM teachers should have, stated that teachers should have content and pedagogical content knowledge at the expert level. In addition, it is important to know different STEM disciplines other than the discipline of expertise that will enable teachers to become effective STEM practitioners in this direction. Teachers can develop knowledge of their discipline by sharing with their colleagues, with cooperation between departments. In Turkey, the lack of what STEM is, its situation in the curriculum and how it will be adapted to the teaching level, and how to train teachers who will explain STEM, continues (Aydeniz and Bilican, 2017). Elimination of these deficiencies will contribute to Turkey's progress in science and technology.

When the literature is examined, it is seen that there are various studies regarding STEM education in which teachers are determined as participants. The study by Özbilen (2018) showed that science teachers knew and used STEM more than teachers from different disciplines. Eroğlu and Bektaş (2016) aimed to determine the views of science teachers about STEM and STEM-oriented activities in their research. In the research, it was determined that the teachers stated that STEM-oriented activities are more related to the discipline of physics in science. The results showed that science is related to technology and mathematics is related to engineering. In addition, it was concluded that the teachers could not practice STEM-based lessons even though they wanted to practice them due to time and material shortages. A study was conducted by Herro and Quigle (2017) examining the perspectives and classroom practices of 21 middle school mathematics and science teachers. This research included teachers' perceptions and practices before and after a PD in which STEAM (Science, Technology, Engineering, Arts and Mathematics) integration is investigated through project-based learning. The research concluded that teachers increased their understanding of STEAM to teach content. It was concluded that they perceived STEAM PD as an effective first step to change the practice, pointing out the importance of collaboration and integrating technology directly into the learning process. EL-Deghaidy et al. (2017) aimed to examine the views of science teachers about the pedagogy and interdisciplinary nature of STEM. At the end of the research, lessons related to teacher self-efficacy, pedagogical knowledge, and creating a collaborative school culture were emphasized. Familiarity with STEM education among school administrators, students, and parents was another important result. In the research, it was determined that teachers expressed their concerns about their unpreparedness to implement STEM applications and engineering was the least mentioned discipline that could integrate with science. Boriack (2013) developed a conceptual framework for effective professional development that leads to change in classroom practices in the study. This study aimed to examine teachers' perceptions of professional development and changes in classroom practices. The data obtained from two programs that provide professional development to teachers in the fields of technology, mathematics and science were used to create the conceptual framework. The results showed that teachers do not perceive professional development related to these fields effectively and do not apply technology in their classrooms despite having high technology self-efficacy.

The current research was conducted with middle school teachers in STEM disciplines. Middle school teachers play a critical role in identifying ways to make STEM subjects more comprehensive and individualized for students (Kier, 2013). The basic knowledge level of teachers in STEM disciplines about STEM education is also considered important in this respect. Determining this level will first reveal how familiar the teachers are with STEM education and how aware they are of STEM education. It will not make sense to include STEM in the curriculum without identifying the deficiencies of teachers who are practitioners of STEM. Teachers who do not have basic knowledge about STEM cannot be expected to apply STEM correctly. The fact that this study has a high original and widespread effect on STEM education makes the research significant. When the studies conducted with teachers and prospective teachers about STEM are examined, it has been determined that there are studies to measure awareness, perception, or attitude about STEM (Çevik, 2017; Çorlu et al., 2015; Hacıömeroğlu and Bulut, 2016; Özbilen, 2018). No study has been found that measures the basic knowledge level of the teachers who are STEM practitioners in terms of the features, goals, benefits, etc. of STEM. In this respect, it can be said that the study is original. It is thought that the current study, which aims to determine the basic knowledge level of teachers about STEM education, will make a significant contribution to the field. With the research, necessary precautions can be taken by determining the basic knowledge level of teachers about STEM education, which forms the roof of the Science Curriculum. In addition, determining the deficiencies of teachers in terms of attainments related to STEM education may lead to future studies.

Aim of the study

Based on the deficiencies in the literature on STEM education in Turkey, the aim of the research was determined. This research aims to determine the basic knowledge level of teachers about STEM education. Sub-questions are:

1. What is the teachers' basic knowledge level of STEM education?
2. Do the basic knowledge levels of teachers about STEM education differ significantly in terms of their gender, discipline, teaching experience, highest qualification, technology use in lessons, participation in a program such as a seminar with STEM content, etc?

METHODOLOGY

Research design

The study utilized the descriptive research method to assess the basic knowledge level of teachers regarding STEM education. It employed Singular and Relational Scanning, which are general scanning models. Singular scanning was used to determine the instantaneous situation and temporal developments, while relational scanning allowed the assessment of the relationship between two or more variables (Karasar, 2016). In the research, factual (gender, discipline, highest qualification, using technology in lessons, participation in a program such as a seminar with STEM content, etc.) and judgmental (STEM Basic Knowledge Level Test scores) quantitative data were collected.

Participants

The research comprised 319 middle school teachers in Turkey, specializing in the fields of science, mathematics, and information technologies. Participation was based on voluntary participation, and the study was conducted during the 2020-2021 academic year.

Demographic characteristics of sampled teachers

A total of thirty-five items were included, combining seven demographic information items with the 28-item STEM Basic Knowledge Test. These demographic items aimed to gather information about factors that could influence teachers' basic knowledge level regarding STEM education.

The data on the demographic information of the teachers in the STEM Basic Knowledge Test are summarized in Table 1.

Table 1. Demographic information of sampled teachers.

Variables	Demographic characteristics	f	%
Gender	Female	173	54.2
	Male	143	44.8
	Missing data	3	1
Discipline	Science	102	32
	Math	138	43.3
	Information technologies	75	23.5
	Missing data	4	1.2
Teaching experience	0-6 years	90	28.2
	7-13 years	97	30.4
	13-19 years	79	24.8
	20 years and Over	49	15.4
	Missing data	4	1.2
Highest qualification	Bachelor's	254	79.5
	Postgraduate	59	18.5
	Missing data	6	2
Technology use in lessons	Never	11	3.4
	Rarely	25	7.8
	Sometimes	106	33.2
	Often	174	54.5
	Missing data	3	1.1
Participation in a program such as a seminar with STEM content, etc	Participated	46	14.4
	Did not participate	264	82.8
	Missing data	9	2.8

FINDINGS AND INTERPRETATION

In this part of the study, the findings obtained from the statistical analysis of the data and comments on them are presented.

Basic knowledge of STEM education

The findings pertaining to teachers' basic knowledge of STEM education are presented in this section. The results regarding the attainment scores are summarized in Table 2.

Table 2 shows that the attainment with the highest average is the seventh attainment (77%). This is followed by the eighth attainment with an average of 73%, the third and fourth attainments with 68%, the second attainment with 65%, and the first and fifth attainments with 62%. The attainment with the lowest average is the sixth attainment with 54%. The average score of all attainments is 66%. Skewness and kurtosis coefficients of the other attainments are in the range of ±1 except for the seventh attainment.

Table 2. Summary of STEM attainment scores.

Attainments	$\bar{X}$	Sd	Skewness	Kurtosis
Attainment 1	.62	.30	-.384	-.667
Attainment 2	.65	.33	-.438	-.768
Attainment 3	.68	.27	-.651	-.479
Attainment 4	.68	.33	-.711	-.638
Attainment 5	.62	.28	-.614	-.459
Attainment 6	.54	.32	-.251	-.906
Attainment 7	.77	.32	-1.168	.179
Attainment 8	.73	.28	-.899	-.061
Total Attainments	.66	.22	-.802	-.343

Findings and interpretation of the second sub-question

Here, the findings related to the second sub-question of the research are given. It was questioned whether the basic knowledge level of teachers about STEM education differed in terms of their gender, discipline, teaching experience, highest qualification, technology use in lessons and participation in a program such as a seminar with STEM content, etc. Since the data were not normally distributed, non-parametric tests (KWH, MWU) were used to analyze.

Do the basic knowledge levels of teachers about STEM education differ in terms of their gender?

Under this heading, the findings regarding whether the basic knowledge level of teachers regarding STEM education differ in terms of their gender are summarized in Table 3.

In Table 3, the total scores of the teachers' STEM Basic Knowledge Test are compared in terms of gender. A significant difference was observed between the total scores of men and women in favor of women (U = 9884.00, $p < .05$).

Table 3. Mann Whitney-U test results of STEM Basic Knowledge Test total score in terms of gender.

Gender	N	Mean rank	Sum of ranks	U	*p* Value
Female	173	172.87	29906.00	9884.00	.002*
Male	143	141.12	20180.00		

Do the basic knowledge levels of teachers about STEM education differ in terms of the discipline?

Under this heading, the findings about whether the basic knowledge level of teachers about STEM education differs in terms of their discipline are given in Table 4.

As shown in Table 4, the total scores of the teachers in the STEM Basic Knowledge Test were compared in terms of their discipline. No significant difference was observed between the total scores of the Science, Mathematics and Information Technologies ($p > .05$).

Table 4. Kruskal Wallis-H test results of STEM Basic Knowledge Test total score by discipline.

Discipline	N	Mean rank	Sd	X^2	*p* Value
Science	102	164.64			
Mathematics	138	147.36	2	3.435	.180
Information technologies	75	168.41			

Do the basic knowledge levels of teachers about STEM education differ in terms of teaching experience?

Under this heading, the findings about whether the basic knowledge level of teachers about STEM education differs in terms of their teaching experience are given in Table 5.

In Table 5, the total scores of the teachers' STEM Basic Knowledge Test are compared in terms of their teaching experience. A significant difference was found between the total scores of teachers with 0-6 years, 7-12 years, 13-19 years, 20 years and more teaching experience ($X^2 = 33.727$; $p < .05$). A difference was found between the scores of teachers with 0-6 years of teaching experience and teachers with 13-19 years of teaching experience in favor of teachers with 0-6 years of teaching experience. When the scores of teachers with 0-6 years of teaching experience and teachers with 20 years and more teaching experience are compared, a difference was determined in favor of teachers with 0-6 years of teaching experience. A difference was found between the scores of teachers with 7-12 years of teaching experience and teachers with 13-19 years of teaching experience in favor of teachers with 7-12 years of teaching experience. A difference was determined in favor of teachers with 7-12 years of teaching experience.

Table 5. KWH test results of STEM Basic Knowledge Test total score in terms of teaching experience.

Teaching experience (year)	N	Mean rank	Sd	X^2	*p* Value	Post hoc
0-6	90	183.66	3	33.727	.000*	1>3; 1>4; 2>3; 2>4
7-12	97	181.02				
13-19	79	128.26				
20 and above	49	113.26				

Note: 1 = 0-6 years, 2 = 7-12 years, 3 = 13-19 years, 4 = 20 years and above
* $p<.05$

Do the basic knowledge levels of teachers about STEM education differ in terms of the highest qualification?

Under this heading, the findings about whether the basic knowledge level of teachers about STEM education differs in terms of their highest qualification are given in Table 6.

As shown in Table 6, a U test was conducted to compare the total STEM Basic Knowledge Test scores of the teachers in terms of their highest qualifications. There was no significant difference between the total scores of teachers with bachelor’s and postgraduate degrees ($U = 6540.50$, $p > .05$).

Table 6. Mann Whitney-U test results of STEM Basic Knowledge Test total score in terms of highest qualification.

Highest qualification	N	Mean rank	Sum of ranks	U	*p* Value
Bachelor’s degree	254	156.75	39814.50	6540.50	.458
Postgraduate	59	146.92	8080.50		

Do the basic knowledge levels of teachers about STEM education differ in terms of technology use in the lessons?

Under this heading, the findings regarding whether the basic knowledge level of teachers regarding STEM education differs in terms of technology use in lessons are summarized in Table 7.

As shown in Table 7, the total scores of the teachers' STEM Basic Knowledge Test are compared in terms of their technology use. A significant difference was observed between the total scores of teachers who had never, rarely, sometimes and often opinions ($p < .05$). A significant difference was observed between the total scores of teachers who had never, rarely, sometimes and often opinions ($p < .05$). A significant difference was found between the teachers who stated that they never used technology in lessons and those who rarely used it, in favor of the teachers who rarely used it. A significant difference was determined between the teachers who stated that they never used technology in lessons and that they sometimes use it, in favor of the teachers who sometimes use it. It has been determined that there is a significant difference between the teachers who stated that they never use technology in lessons and that they use it often, favor of the teachers who use it often.

Table 7. KWH test results of STEM Basic Knowledge Test total score in terms of technology use in lessons.

Technology use in lessons	N	Mean rank	Sd	X^2	*p* Value	Post hoc
Never	11	39.64	3	23.952	.000*	2 > 1; 3 > 1; 4 > 1
Rarely	25	143.02				
Sometimes	106	151.86				
Often	174	172.28				

Note: 1 = never, 2 = rarely, 3 = sometimes, 4 = often. * $p < .05$

Do the basic knowledge levels of teachers about STEM education differ in terms of participation in a program such as a seminar with STEM content, etc?

Under this heading, the findings about whether the basic knowledge level of teachers about STEM education differs in terms of their participation in a program such as a seminar with STEM content, etc. are given in Table 8.

In Table 8, the total scores of the teachers' STEM Basic Knowledge Test are compared in terms of their participation in a program such as a seminar with STEM content, etc. A significant difference was observed between the total scores of the teachers who stated that they agreed and did not agree, in favor of the teachers who stated that they did not agree (U = 4588.00, $p < .05$).

Table 8. Mann Whitney-U test results of STEM Basic Knowledge Test total score in terms of participation in a program such as a seminar with STEM content, etc.

Participation in a program such as a seminar with STEM content, etc.	N	Mean rank	Sum of ranks	U	*p* Value
Participated	46	123.24	5669.00	4588.00	.008*
Did not participate	164	161.12	42536.00		

* $p < .05$

DISCUSSION AND CONCLUSION

In this section, we summarize the key findings and implications of our study and discuss the conclusions. Our research revealed that the overall STEM basic knowledge level among middle school teachers in our study cohort was 66%. This suggests that there is room for improvement in terms of teachers' understanding of STEM education concepts and principles. And this could be the first crucial step in promoting teachers in STEM education. One potential explanation for the relatively low STEM basic knowledge level is the absence of STEM-related education during teachers' undergraduate training. This underscores the need for more comprehensive STEM-focused teacher preparation programs. Our findings align with previous research, such as Weng et al. (2020), which highlighted the insufficient STEM knowledge among teachers. Twaddle and Smith (2023) also found that pre-service teachers' STEM pedagogical content knowledge scores were average, further emphasizing the need for improved STEM education training.

Interestingly, our study revealed that female teachers exhibited a higher STEM basic knowledge level compared to their male counterparts. This finding is consistent with Rahman et al. (2021), who reported higher STEM-based education knowledge scores among female teachers. However, it is worth noting that Hacıömeroğlu (2018) arrived at different conclusions in their study on STEM teaching orientation among prospective teachers. In the study, there was no significant difference in the scores of prospective teachers in terms of gender. We found no significant differences in STEM basic knowledge levels among teachers based on their disciplines. This outcome is in line with Çınar et al.'s (2016) research, which also found no significant distinctions between science and mathematics teachers in terms of STEM-related views.

Surprisingly, our study showed that teachers with the least experience (0-6 years) exhibited the highest STEM basic knowledge level. And the teachers with the most experience (20 years and over) exhibited the lowest. This may be due to the fact that the constructivist approach in curricula is not very old. With the implementation of this approach since 2005, new-generation teachers are trained with this awareness. However, teachers who have more teaching experience may not have fully adopted this approach. Also, STEM education can be characterized as an approach that includes the characteristics of the constructivist approach. This finding is consistent with Rahman et al (2021), who concluded the highest average score for STEM-based education knowledge among teachers with less than 10 years of teaching experience. However, the results of another study showed that teachers with 6-15 years of experience were least familiar with engineering features (Hsu et al., 2011).

Interestingly, we found no significant differences in STEM basic knowledge levels among teachers based on their highest qualifications. This outcome may be due to the fact that the teachers did not take any graduate-level courses regarding STEM in the curriculum and did not participate in STEM-related education. Our study showed that teachers who never use technology in lessons had a lower STEM basic knowledge level than teachers who rarely, sometimes and often use it. The findings of Boriack (2013) differ from ours. In the study, it has been determined that although teachers have high technology self-efficacy, they do not apply technology in their classrooms. Surprisingly, teachers who did not participate in a program such as a seminar with STEM content, had a higher level of basic knowledge about STEM education than the teachers who participated. As the reason for this situation; it can be said that the STEM seminars which the teachers participated in, are not qualified or there is no effective participation. As a matter of fact, in the study of Özbilen (2018), which determined STEM awareness of the teachers and got the opinions of the teachers; it was concluded that teachers had problems getting training on STEM education, most of the teachers were not aware of the training, and they could not participate the trainings they were aware of due to the lack of quota. Gözüm et al. (2022) reported a significant difference in the STEM pedagogical knowledge scores of teachers about having STEM training or not. However, contrary to our study, the difference was in favor of STEM-trained teachers.

Some suggestions can be made based on the findings of this study. Teachers with teaching experience of more than 20 years could be encouraged to participate in STEM education programs. The quality of the training programs related to STEM education can be increased. It may be also recommended to give courses on STEM education at the postgraduate level. In this study, results were obtained for the basic knowledge that teachers should have for STEM education. Conclusions showed that there is room for improvement in terms of teachers' understanding of STEM education concepts and principles This can serve as a guide regarding the position of teachers in STEM education. It can be used to evaluate whether teachers are ready at the basic knowledge level for STEM education.

This study has several limitations that influence the generalization of the findings. For example, our study was conducted with middle school STEM teachers. It will be beneficial for future studies, including participants from different levels of teachers and disciplines. An additional limitation is that we used the STEM Basic Knowledge Test in the research to gauge teachers' basic knowledge levels. The scope of this study can be widened by examining the opinions of teachers on STEM education.

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Data availability: The datasets generated during this study are not publicly available but data will be provided by the corresponding author upon request.

Declarations

Informed consent: Informed consent was obtained from all individual participants included in the study. Their names and the collected data remained confidential.

Disclosure of potential conflicts of interest: The authors declare that they have no conflict of interest.

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