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TEACHERS' PERSPECTIVES ABOUT THE MEANING OF STEM: A CASE FROM TÜRKİYE

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Abstract

STEM (Science, Technology, Engineering, and Mathematics) Education has become a necessity for a science and technology-driven world. There is an increasing emphasis on STEM education from the economic, political, and education sectors. The success of STEM education is possible with the effective implementation of STEM teaching strategies applied by teachers. Thus, teachers' practices and understanding of STEM education are crucial. As an effort to understand, teachers' practices of and opinions about STEM, this study explored science teachers' perceptions about STEM education. Ten science teachers working in primary schools in Türkiye participated in the study. Semi-structured interviews were conducted with the participants. The data obtained from semi-structured interviews were analyzed by using content analysis. Teachers' perceptions were examined under four categories: Teachers' perception of the integration of science, the applicability of STEM in Türkiye, the benefits of STEM education, and the barriers to effective STEM education. While teachers mainly addressed the need to integrate different disciplines in science education and the importance of introducing STEM to science classes, they aligned several factors such as schooling structure, resources and technology infrastructure, student characteristics, teacher readiness, and cultural appropriateness as potential barriers.

Keywords: Integration, perceptions, science teachers, STEM education.

INTRODUCTION

STEM (Science, Technology, Engineering, and Mathematics) Education has become a necessity for a science and technology-driven world. Moreover, numerous reports (such as Ministry of National Education [MoNE], 2016; National Research Council [NRC], 2011) acknowledged the importance of STEM for raising active citizens who will face the challenges of this science and technology-driven world. The term STEM (abbreviation of science, technology, engineering, and mathematics) was first used in the United States by the National Science Foundation in the late 1990s. The acronym was first SMET, but after receiving negative feedback, it was changed to STEM (Sanders, 2009; Williams, 2011). Since its introduction, it has evolved and changed constantly. While its emergence rested on a political agenda (government calls for increasing the number of students selecting STEM disciplines as a career path) in the 1990s, it was enacted as S.T.E.M in schools (separate teaching of each discipline rather than integrating STEM disciplines) (Blackley & Howell, 2015). The definition of STEM education has been debated for a while for numerous reasons (Honey, Pearson, & Schweingruber, 2014; Sanders, 2009). One reason is that the disciplines in the acronym are not usually pedagogically related (Hallström & Ankiewicz, 2019) and these disciplines tend to be taught separately (Pearson, 2017). Another reason that Bybee (2010) stated is that engineering is not a subject being taught in primary and secondary school curricula. One last reason is the role of technology in the acronym is often confusing (Williams, 2011). Still, there is an ongoing effort to define STEM education. According to Sanders (2009), STEM education implies 'teaching and learning between/among any two or more of the STEM subject areas, and/or between a STEM subject and one or more other school subjects' (p.21).

Consequently, STEM education emerged as a meta-discipline that emphasizes invention, problem-solving, and technology use (Kelley & Knowles 2016). Students participate in authentic contexts for meaningful learning and applying science and/or mathematics to produce technologies (Kelley & Knowles 2016; Moore et al., 2014). According to Stohlman et al. (2012) integrated STEM education is an approach to combine STEM disciplines in a meaningful way within the class while it is not necessary to involve all STEM disciplines at once. The key point is making integration intentional and relevant to students' lives (NAE & NRC, 2014).

The impact of STEM education on students is varied in the literature: Learning (Kelly & Knowles, 2016; Moore et al., 2012; 2014), achievement (Becker & Park, 2011; Eroğlu & Bektaş, 2022; Guzey et al., 2017; Sayılgan, Akkuş & Yıldırım, 2022; Yıldırım & Altun, 2015), attitudes (Gülhan & Sahin, 2016, Karışan & Yurdakul, 2017; Şimşek, 2019); motivation (Aktamış & Hiğde, 2022; Gokbayrak & Karisan, 2017; NAE & NRC, 2014; Pearson, 2017; Tillman et al., 2014), student engagement (Shernoff, 2013; Şimşek, 2019), science process skills (Hiğde & Aktamış, 2022; Uysal & Cebesoy, 2018; Şimşek, 2019), higher level thinking skills (Moore et al., 2012), engineering design skills (Ozkizilcik & Cebesoy, 2023), problem-solving skills (Özkızılcık & Cebesoy, 2020) and scientific creativity (Doğan & Kahraman, 2021; Eroğlu & Bektaş, 2022) were reported to be affected positively. From relevant literature, we can conclude that STEM education has important premises for students. However, it must be noted that successful STEM education requires effective instructional practices (Breiner et al., 2012; Wang et al., 2011). While instructional practices are reported to be crucial factors, the curriculum structure and teachers' lack of skills and preparation for teaching STEM are two key factors for failure in the successful integration of STEM education in school settings (Blackley & Howell, 2015).

STEM Education and Teachers

Teachers' perceptions about STEM, understanding and knowledge in STEM is linked to their classroom applications (Bell, 2016). However, the literature acknowledges that teachers need better preparation for effective integrated STEM education (DeCoito & Myszkal, 2018; Guzey, Moore & Harwell, 2016; Guzey et al., 2014). However, traditional discipline-based teaching is still dominant in the schools which is an important barrier for transforming discipline-based teaching to integrated STEM teaching (Nadelson & Seifert, 2017; Shen, Liu & Sung, 2014). Moreover, moving towards integrated STEM education is often acknowledged as difficult by teachers (Guzey et al., 2016; Margot & Kettler, 2019; Radloff & Guzey, 2016). Lack of understanding (Stohlman et al., 2012), lack of integrated curriculum materials (Guzey et al., 2016; Nadelson et al., 2013; Roehrig et al., 2012), limited content knowledge (Eijwale, 2013; Sanders, 2009; Nadelson et al., 2013; Ring, Dare, Crotty & Roehrig, 2017), limited STEM knowledge of teachers (Nadelson & Seifert, 2017), confidence and efficacy for teaching STEM (El-Deghaidy & Mansour, 2015; Nadelson et al., 2013; Zeldin, Britner, & Pajares, 2008) were frequently reported as barriers for teachers to implement integrated STEM activities and lessons. One way to overcome these aforementioned difficulties is through professional development (PD) programs for in-service teachers. Indeed, the relevant literature report that PD programs enhanced teachers' task-specific engineering and scientific skills (Hardre et al., 2013) and positive perceptions of STEM education (Herro & Quigley, 2017; Wang et al., 2011), implementation of engineering design-based STEM skills (Guzey et al., 2014), reduced their perceived barriers for effective STEM teaching (Herro & Quigley, 2017), increased content knowledge of, confidence for, comfort with, and efficacy for teaching STEM content (Nadelson et al., 2013). In a similar vein, Shernoff, Sinha, Bressler, and Ginsburg (2017) reported that teachers also acknowledged the importance of teacher preparation during undergraduate education. Consequently, it was reported that preparing teachers to teach STEM can be accomplished through teacher preparation programs (Bybee, 2013; English, 2016; Shernoff et al., 2017).

STEM Education and Türkiye

STEM education is a relatively new terminology for the Turkish Education system. The first report about STEM education in Türkiye reported that there is a decrease in the number of students pursuing STEM careers in the university (Akgündüz et al., 2015). Accordingly, MoNE (2016) published a report and presented the trends in STEM education all around the world and the need for STEM education in the Turkish Education System. Turkish Industry and Business Association (TUSIAD) also published another report for showing the need for STEM professionals in Turkish industry through 2023 (TUSIAD, 2014). Altogether these reports have culminated in a curriculum change in primary and secondary science and mathematics curriculum in Turkey in 2018 (MoNE, 2018). As a result, a new skill set 'engineering and design skills' is explicitly addressed in the revised science curriculum. Students are expected to integrate science with math, engineering, and technology to find interdisciplinary solutions to problems by inventing and creating innovative products (MoNE, 2018). Consequently, teachers' own preparedness for implementing the curriculum change became a question. Bell (2016) indicated that teachers' perceptions of STEM, their understanding of STEM and their expertise in implementation are crucially important in successful STEM delivery. Indeed, there were numerous efforts to explore science teachers' perceptions about STEM and its applicability in Türkiye to date. For instance, Eroğlu and Bektaş (2016) investigated perceptions of science teachers who joined a STEM education workshop about STEM education. The teachers associated STEM-based activities with physics and they could make explicit connections among mathematics and engineering. Doğan and Saraçoğlu (2021) also explored science teachers' perceptions of STEM after participating a local workshop provided by research and development team of regional Provincial Directorate of National Education. They reported similar findings about teachers' willingness to implement STEM-based activities in their classrooms in addition to the need of similar PD programs for teachers. In another study, Özcan and Koştur (2018) explored early career science teachers' perceptions of STEM. The study reported that science teachers with one to two years of experience were knowledgeable about the definition of STEM. Bakırcı and Kutlu (2018) also explored science teachers' views about STEM education who were working in a city located in eastern region of Türkiye. In another study, Timur and İnançlı (2018) explored pre-service science and in-service science teachers' perceptions of STEM and reported that pre-service science teachers were more aware of STEM education. A more recent effort by Atalay and Öner Armağan (2023) explored perceptions of teachers working in the city of Türkiye about STEM education. They reported that while teachers were able to make explicit connections between science and other disciplines, they were able to make connections among STEM activities and concepts in physics such as simple machines, electricity, and energy. All the aforementioned studies reported barriers in front of successful STEM implementation in schools such as lack of material (Atalay & Öner Armağan, 2023; Bakırcı & Kutlu, 2018; Doğan & Saraçoğlu 2019; Eroğlu & Bektaş, 2016), time (Bakırcı & Kutlu, 2018; Doğan & Saraçoğlu 2019; Eroğlu & Bektaş, 2016), student readiness (Atalay & Öner Armağan, 2023), teacher preparation (Atalay & Öner Armağan, 2023; Özcan & Koştur, 2018), lack of knowledge in STEM education (Bakırcı & Kutlu, 2018; Timur & İnançlı, 2018), crowded classrooms (Doğan & Saraçoğlu 2019), the inconsistency between the curriculum and the STEM objectives (Özcan & Koştur, 2018) and the difficulty in measuring and evaluating STEM activities (Doğan & Saraçoğlu 2019). These studies were either conducted with science teachers after participating in a PD program (Eroğlu & Bektaş, 2016; Doğan & Saraçoğlu 2019), with science teachers working in a city in Türkiye (e.g., Bakırcı & Kutlu, 2018), or with early career science teachers (Özcan & Koştur, 2018). However, to the best knowledge, we did not encounter any studies focusing on science teachers' perceptions of STEM by using maximum variability sampling techniques. Our study included participants with different teaching experience years (early career to experienced science teachers) and working in different regions of Türkiye. Consequently, this study aimed to explore science teachers' perceptions of STEM, its applicability, benefits and the barriers in front of successful STEM integration. Specifically, we sought to answer the research questions below:

1. What do the science teachers think about the integration of science with other disciplines?
2. What do the science teachers think about the applicability of STEM education?

3. What do science teachers think about the benefits of STEM activities for students?
4. What do the science teachers think about the barriers to STEM education?

METHOD

Research Model

For this purpose, in the current study, the phenomenological method, one of the qualitative research methods, was employed to elicit the opinions of teachers' practices and opinions about STEM and science teachers' perceptions of STEM education.

Phenomenological research, one of the qualitative research designs, is a research design in which, as mentioned before, a subject or situation that is not known in depth but about what we have some idea about to the same extent is examined in depth, and individuals' perceptions and interpretations of phenomena are revealed (Sığrı, 2018). Creswell (2013) defines it as "research that determines the common meaning of the lived experiences of several people about a phenomenon or concept". The reason for choosing the phenomenological design in the current study is to examine the opinions of teachers about the phenomenon of STEM education.

Data Collection, Analysis, and Coding

The main data collection method used in phenomenological research is interviews. Similarly, Creswell (2013) also mentions that the data collection process in phenomenological research includes "interviews with individuals who have experienced the phenomenon". In the current study data collected by semi structured interview protocol which was developed by the researchers. Before the interview form was developed, the existing literature was reviewed. On the basis of this literature review, the draft interview form was created. After constructing interview questions, we sent the interview question to four external researchers who held PhDs in the field of education who are also interested in STEM for clarity of meaning. In addition, it was submitted to the review of an expert to check the language and comprehensibility of the interview items. In line with the feedback from the experts, the interview form was given its final form. In the interview form, there are items to elicit the participants' perceptions about STEM at school in Turkey.

All interviews were conducted face-to-face in the participants' working environments. Each interview was audio-recorded with a voice recorder after informing the participants. An approximately 25 min. ongoing interview was conducted with each participant. While conducting the interview, the researcher tried to follow a systematic way. At the end of each interview, a preliminary analysis was conducted and researcher notes were taken. When needed, the interviewees were re-contacted. After the interviews, all the audio records were transcribed and coded. The data obtained from the interviews were transcribed simultaneously with the data collection process. These transcripts were coded by each researcher and analyzed by using the content analysis method.

Research Group

It is stated that in phenomenological studies, "a heterogeneous group whose size varies between 3-4 people and 10-15 people" should be focused on (Creswell, 2013). The participants of the current study are 1o teachers who is graduated from educational faculty participating in the study on a volunteer basis. Maximum variability sampling, which is one of purposeful sampling methods, was used in determining the study group. The characteristic of participant is given at the Table 1.

Table 1 Characteristics of Participant

Participant code	Teaching experience	Current school	Previous schools worked	Courses given
T1	4 years	Village school	Village school	Science, elective course about science
T2	2 years	Village school	Village school	Science, elective course about science

T3	1 year	Village school	None	Science, mathematics
T4	11 years	School located in city center	Village schools	Science, technology design, information technologies
T5	3 years	School located in city center (private)	None	Science, elective course about science
T6	7 years	School located in city center	None	Mathematics
T7	7 years	School located in city center	Village schools	Science
T8	8 years	School located in city center	Boarding school, School located in city center	Science
T9	14 years	School located in city center	Village school, boarding school, School located in city center	Science
T10	10 years	School located in city center	School located in city center	Science, technology design

Credibility, Transferability and Dependability

Two researchers coded the verbatim texts separately and then compared each coding to reach a consensus between coders. In order to ensure the *dependability* of the study, the researchers analyzed all the data in two different periods individually and then compared their analyses. After all the codes were established, the sub-codes were determined and then the codes were revised. In order to ensure the *credibility* of the study, while developing the interview form, a conceptual framework was created by examining the relevant literature. While these interviews were going on, the data obtained from the interviews were confirmed by the participant confirmation method by asking questions such as "Is it like this?", "Have I understood correctly?" After the interviews, the participants' statements were analyzed and these analyses were confirmed by the participants. Finally, all the data were first analyzed by the two researchers together and then individually. To ensure the *transferability* of the study, the findings obtained in the data analysis are given in detail by the direct quotation method without any comment. What has been done in the process is explained in detail. In order to ensure the dependability of the study, the raw data, and analyses obtained are stored by the researchers so that they can be examined by others for possible confirmation in the future.

In terms of the ethical dimension, the most important priority of the researchers is the confidentiality of the participants. The content of the study and the research questions were shared with the participants before the interview. The participants were verbally re-informed about the study's framework and ethical codes before the study and their consent was gained through voice recording. After the completion of the reporting process, the full text was shown to the participants and the publishing process was initiated after their approval was received. All the participants are coded as T1, T2, T3, and so on. Any confidential data that could reveal the identity of the participants were shared.

FINDINGS and RESULTS

Based on the research questions guiding this study, we divided the findings into four sections: (a) Findings about teachers' perceptions of integrating science with different disciplines, (b) the applicability of STEM in Türkiye, (c) the benefits of STEM activities for students and (d) the barriers to STEM implementation.

Before exploring the findings, we also asked the teachers whether they had ever heard of STEM or not. While six teachers said '*yes but partially'*, four teachers indicated that they did not hear about STEM. The teachers who were partially familiar with STEM indicated that they were aware of the STEM acronym and acknowledged STEM education as an approach that could be used in educational contexts but were not sure about what STEM education consists of and what activities could be regarded as STEM activities. Only one teacher (T7) was aware of STEM and indicated the importance of STEM in a science and technology-driven society.

> *I have heard of STEM. As the program has pitfalls, STEM is necessary. In order to improve the program, it is necessary to have a scientific-mathematical pillar and a verbal-linguistic pillar at the same time. The reason why it is necessary is that students are already trying to understand nature, trying to make sense of science, and everything related to science, actually, there must be math to make it possible, that is, there must be technology today to make math possible, so to put it briefly, STEM stands out as a very important requirement for the program.*

Findings about teachers' perceptions of integrating science with different disciplines

The first theme was teachers' perceptions of the integration of science with other disciplines. The teachers indicated that science itself is related to all disciplines. For instance, T1 indicated that:

> *We can integrate all disciplines into science education because science is like life itself because science covers all parts of life. I mean, we can integrate our course into almost disciplines*.

In a similar manner T2 indicated:

> *Science is actually life itself. It covers everything. So let me put it this way. The first question I ask kids when I explain heat concept is this: 'How does your mother make pasta at home?' They are all surprised. They explain how she does it. She puts the water in, then boils the pasta, and so on and so forth. I ask again: 'When does she put the salt in? Does she put the salt at first or after it boils?' They all say after it boils. That is the experience of mothers: If she adds salt beforehand, the water will boil later, so she adds salt after the water has boiled to prevent the gas from running out. The mothers do not know the scientific explanation. But the scientific explanation is this: Salt raises the boiling point of water, so the water boils later. Life is science. Science is related to everything. This is the simplest example.*

We then asked which disciplines specifically they believed that science is related. The disciplines with which science is associated are shown in Figure 1:

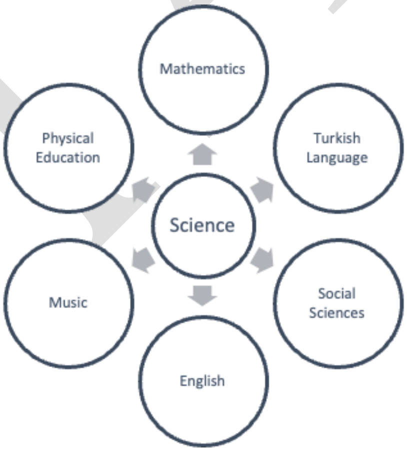

Figure 1. Teachers' perceptions about the integration of science with other disciplines

As expected, all the teachers indicated that science was primarily related to mathematics and Turkish language courses. Besides mathematics and Turkish language courses, the teachers indicated that science is related to other disciplines such as music, physical education, English, and social sciences. Sample excerpts explaining how teachers explained that science is connected to other disciplines are presented in Table 2.

Table 2. Sample excerpts explaining the connection between science and other disciplines

Teacher ID	Disciplines related	Sample excerpt
T3	Mathematics	We benefit from mathematics. Part of science is numerical and what I mean, one leg is numerical. Many students have problems with mathematical operations. For example, if there is a formula, let me explain it with an example. For example, when we calculate density, we say mass is divided by volume. But if we ask for the volume instead of dividing the density by the mass, the child cannot deduce it.
T5	Turkish language	Science is related to other fields, especially Turkish and mathematics. First of all, being able to understand what you read is important. Science questions are now related to being able to interpret what you read. The student can be successful in science if he/she can understand the explanations given or if he/she can understand what he/she reads in general.
T1	Music	We also benefit from music lessons: We have a sound unit in 8th grade. How does the pitch, thinness, thickness, and frequency of the sound in musical instruments affect whether the sound is thin or thick? For example, we use music class for this. We ask our students who play musical instruments to bring their instruments. We even try out these musical instruments. How does it sound when it is tuned, how does the string sound when it is tight, how does it sound when it is loose? Then, for example, our students who play the darbuka, and how it affects the sound when the surface is wide, for example, we also used them in our lessons. We also benefit from the music.
T9	Physical education	There is a topic on nutrients in the 5th grade. Nutrients are categorized: energizing, constructive, or restorative Actually, it is also related to physical education. Another example is at the 6th grade level: the circulatory system… When you run too much, your heartbeat speeds up. By trying this in physical education class, students can actually discover it there.
T1	Social sciences	In social studies, students learn about natural and historical beauties and the places where they are located. In science class, there are units on them, or if they know their names and characteristics well, they can better understand how these living things adapt to the place where they live and make better inferences when we study species, habitat, and population in science class.
T8	English	Since science is a subject at the center of life and human beings, it has common denominators with all subjects. I think the secret of success in science is to benefit from all subjects. Let me give you an example from English. We shorten the word "force" to "f", I tell them that it comes from the English word force, I make a connection between science and English.

Findings about the applicability of STEM in Türkiye

We asked the teachers whether STEM education can be used in the Turkish education system. Out of the 10 participants, eight of the teachers said that they believe that it can be implemented in the school curriculum. Sample excerpts voicing their opinions are provided below:

> ‘*I think it is a good thing to implement this model [referring to STEM education]. Because science is a subject that prepares people for life. In other words, the children should be able to use the information that they have learned in their lives after they have left school. It should not just be a theoretical lesson. That's why I think we should apply it to everyday life. I think we should even increase STEM activities in science courses. In other words, the science courses should be functional. When we apply STEM activities more, the science courses can be improved.' (T1)*

> *‘I think such activities [referring to STEM activities] will be beneficial because engineering is already a field related to science and mathematics.' (T3)*

> *‘I think STEM activities are necessary for the science curriculum. It is always better to concretize the concepts than to memorize them.' (T8)*

Only two teachers (T2 and T6) were hesitant about the applicability of STEM education in Türkiye. Their reluctance was due to either inadequate school infrastructure (T2) or the high school entrance exam (T6). Their excerpts are provided below:

'We are renewing the curricula, but these curricula are made according to those in Çankaya [referring to the city in which MoNE headquarters are found]. They never think about our school or consider the schools in a village and design the programs accordingly. My school lacks many materials. You will not believe it, there are not many materials in my school, not even the most basic experimental materials for conducting simple science experiments.' (T2)

'As long as students have that kind of test anxiety [referring to the high school entrance exam], I do not think we will be successful in introducing STEM education into our education system. It will be just a name change as a system.' (T6)

Findings about benefits of STEM education

The third theme was science teachers' opinions about the possible benefits of STEM education. Science teachers were generally positive about the benefits of STEM education. Their opinions were grouped under four categories: (a) interest, (b) class participation, (c) efficient learning and (d) learning by doing and experiencing (see Figure 2).

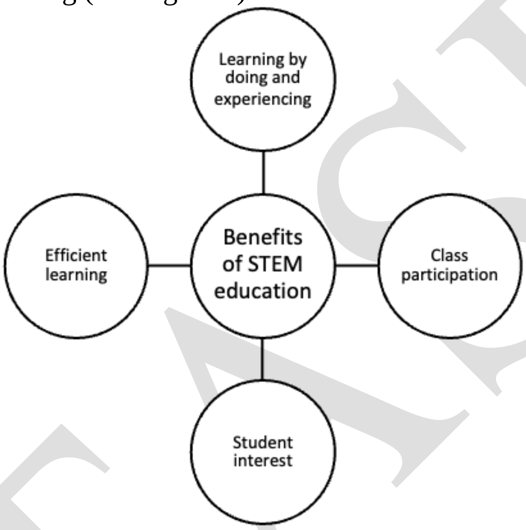

Figure 2. Teachers' opinions about possible benefits of STEM education for student participation

All teachers indicated that STEM education in general and STEM activities will enhance student interest and attention in science classes.

'I believe that such STEM activities may be more beneficial for students to learn by doing and experiencing. Moreover, they will easily remember what they have done themselves.' (T3-learning by doing and experiencing)

'I think it is [referring to STEM education] a necessity for our country, because after graduating from school, students usually cannot transfer what they have learned in school to everyday life, they cannot use it. In other words, after graduating from school, a student should be able to easily apply the knowledge they have learned in school to their daily life, they should be able to apply it to their daily life. This is possible with STEM education.' (T1-efficient learning)

'I think this kind of STEM activities will make the child's brain more active and allow for more effective learning.' (T5-effective learning)

'Such STEM activities allow students to become more engaged in the science classes.' (T8-class participation)

'I think it would be good to do STEM activities. It would capture students' attention and interest.' (T2-student interest)

Findings about the barriers to STEM education

The last theme found in teachers' responses was teachers' perceptions about barriers to STEM education. In fact, teachers stated a range of barriers to effective STEM education. These barriers can be categorized under four major themes as: (a) cultural appropriateness, (b) students related factors,

(c) school system and (d) school structure. Figure 3 shows the major themes and categories under these themes:

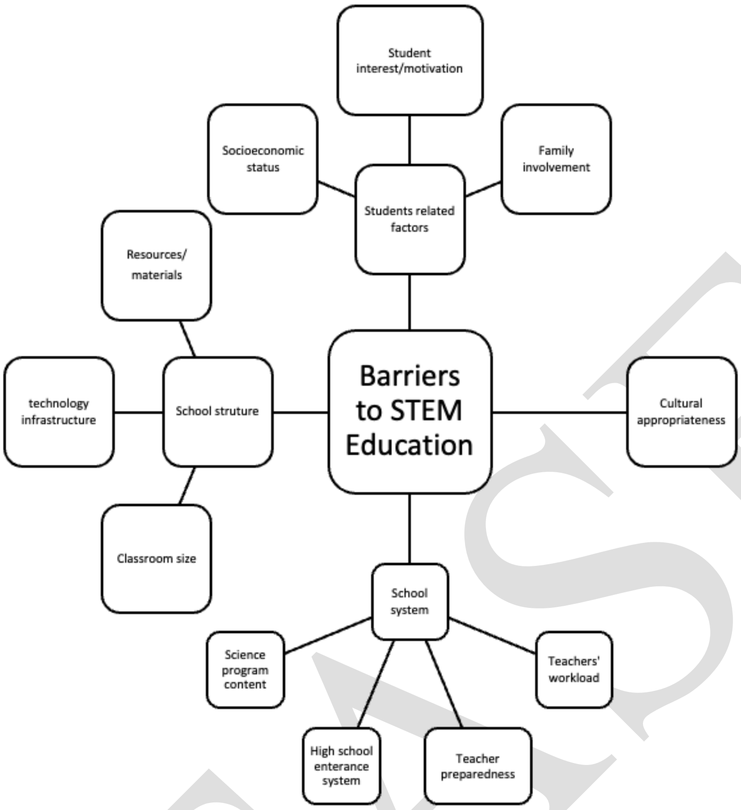

Figure 3. Teachers' opinions about barriers to effective STEM education

The school system and school structure were the two most common themes found among teachers' responses. While classroom size, technology infrastructure, and resources/materials were grouped under the school structure theme; high school entrance exams, the content of the science program, teacher workload, and preparedness were grouped under the school system theme. Teachers frequently stated some concerns rooted in the school system in Türkiye. Sample excerpts are provided below:

> *'Since engineering is already a field related to science and mathematics, such activities [referring to STEM activities] will indeed be useful. But I think teachers need to be trained. I mean, there are many science teachers who even do not use the simplest form of a simple electrical circuit in their courses.' (T3- teacher preparedness)*

> *'I was a classroom teacher of a class. However, I could not visit the families of the students in the class during the week, because I was teaching 35 hours a week. I mean, I was teaching 32 hours in science, and I was also teaching an extra three hours because I had to. When exactly could I do STEM activities in my class?' (T6-workload)*

> *'Of course, in the current examination system, as I said before, students are more test-oriented and test-successful, and this situation pushes us to solve tests and acquire test-solving techniques. After all, the number of correct answers is taken into consideration. For example, what is a student's ideal? To go to a science high school. What should s/he do to go to science high school? S/he has to solve more questions.' (T5- high school entrance exam)*

> *'One of my own students, who was in the 7th grade at that time, did not want to take physical education course because of this exam [referring to high school entrance exam]. I was his class teacher, but we made him take the physical education class. He was worried about the exam.' (T9- high school entrance exam)*

> *'It is important for us to keep up with the topics in class. The content of science courses is very intense, even though it has been reduced, it is much less intense than it used to be, but it is still very intense. Because we also try to do experiments, I think there should be a separate hour for conducting experiments. Since I also have to do the experiments in the class, it is difficult to keep up with the topics.' (T1-the content of science lessons)*

Apart from school system-related problems, science teachers in this study frequently indicated that school structure-related problems such as *classroom size* (i.e., high number of students in a class), *insufficient technology infrastructure* (i.e., internet connection, up-to-date computers, lack of technicians who would provide repair support) and *resources/materials* (i.e., lack of materials to conduct science experiments or science laboratories). Below, sample quotations representing each category are presented:

> *'I had 42-43 students in a class. How could I able to use STEM activities with these 43 students.' (T6-classroom size)*

> *'There are so many students in my class that it takes time for me to get them to the lab in the most secluded corner of the school.' (T2, classroom size)*

> *'We even have problems connecting to the Internet. Since I work in a village school, I have Internet connection problems. I can send the tests to the students as homework, and I can follow them from there. We can get their reports, which student has done it, how many questions have been solved, and how much of the homework has been done. The reports came to us. But since there is no Internet access, we cannot use it effectively.' (T9-technology infrastructure)*

> *'There are no materials, no materials to do the simplest experiments. The materials have already been broken here and there, somehow broken while being transported from one place to another.' (T2- lack of materials)*

Another important theme revealed was student-related factors as a barrier to effective STEM implementation. Teachers stated that student interest/motivation, family involvement, and socioeconomic status are important factors that could hinder effective STEM implementation.

> *'This method [referring to STEM education] can be successful with students who also receive family support.' (T4- family involvement)*

> *'Students need to be interested in these kinds of activities. [referring to STEM activities] I think they need to have time to do these kinds of activities.' (T8-student interest)*

> *'I work in a suburban school with a low socioeconomic level. The students here do not have the budget for these activities [referring to STEM activities].' (T6-socioeconomic status)*

The last theme revealed was cultural appropriateness. Few teachers stated that STEM education was not appropriate for the Turkish education system since it was exported from other countries.

> *'Where is the cultural appropriateness? They import it from somewhere else. The bureaucrats in Ankara also decided that this program is suitable for us. Did they come and see my school?' (T2)*

> *'This approach called STEM, must be indigenous. Put the 'E' in English and the 'H' in Health and create your own approach. Is that it? There should be some cultural appropriateness.' (T7)*

DISCUSSION, CONCLUSION, and RECOMMENDATIONS

The results of this study revealed important points: First of all, the teachers believed that science courses could be integrated with a range of disciplines including mathematics, literacy, English, social sciences, physical education, and music. All teachers indicated a visible and strong connection among science, mathematics, and literacy. Other disciplines were less frequently expressed. This finding is aligned with existing literature which reported that science is closely related to other disciplines (e.g., Atalay & Öner Armağan, 2023; Doğan & Saraçoğlu, 2019; Eroğlu & Bektaş, 2016). For instance, Eroğlu and Bektaş (2016) reported that science teachers made explicit connections among science, mathematics, and engineering. Doğan and Saraçoğlu (2019) also reported a similar connection in their study. Engineering was not a discipline that was stated by the teachers in our study. As Eroğlu and Bektaş (2016) and Doğan and Saraçoğlu (2019)'s studies were conducted with science teachers who participated in the PD program for STEM education, it could be the reason why the participating teachers were able to make connections with engineering and science. In our case, the participating teachers did not join any formal training about STEM education.

Another significant finding revealed was that teachers valued the importance of STEM education as it creates opportunities for students to enhance effective learning, active participation, learning by doing, and increase student interest in science and technology. This finding was supported by Margot and Kettler's (2019) study. In their study, Margot and Kettler (2019) explored teachers' perceptions of STEM integration and education by using a systematic literature review approach. They revealed that science teachers do value STEM education and integration in their classes. In a similar manner, El-Deghaidy and Mansour (2016) reported that teachers acknowledged the importance of STEM education by indicating that STEM education can promote skills that are required for the 21st century including critical thinking, collaboration, and problem-solving. Moreover, Bell (2016)'s study indicated that teachers' beliefs about the importance of STEM education could be an indicator of their classroom practices. Thus, the successful integration of STEM education in science courses could be possible with teachers who intrinsically believe in the importance of STEM education. The studies conducted in the Turkish context reported similar findings (e.g., Doğan & Saraçoğlu, 2019; Eroğlu & Bektaş, 2016). As Eroğlu and Bektaş (2016)'s study was conducted with science teachers who participated in the PD program for STEM education, it was an expected outcome to observe these teachers acknowledge the importance of STEM education. In our case, the participating teachers were chosen by using maximum variation and had varying teaching experiences. In fact, teaching experience was a factor that influenced teachers' perceptions about the importance of STEM education. Margot and Kettler (2019) revealed that teachers' experience was a major factor influencing teachers' perceptions. In line with this finding, Özcan and Koştur (2018) who investigated early-career science teachers' perceptions of STEM education reported that early-career teachers were able to give comprehensive, detailed, and accurate answers to the question "What is STEM?". This might be related to the recent curriculum revision in science teacher education programs. In line with science curriculum change in 2018, science teacher education programs have also been revised in 2018. Accordingly, a compulsory course entitled 'Interdisciplinary Science Teaching' which aims to develop teachers' capabilities of interdisciplinary teaching was introduced. Thus, it could be possible that newly graduated science teachers might be more knowledgeable about STEM education. In line with this, Timur and İnançlı (2018) explored science teachers' and pre-service science teachers' perceptions of STEM education and reported that pre-service science teachers were more knowledgeable about STEM education and its applications. Even though those studies were not conducted with teachers who graduated after the science teacher education program change, there still might be a chance to join STEM training provided for pre-service science teachers during their undergraduate education.

The last theme was related to possible barriers to effective STEM education in schools. Teachers provided a rich and detailed list of barriers to why STEM education and STEM activities might not be implemented effectively. The main reason stated by teachers is the school system including teacher workload, high school entrance exams, content of science courses, and teacher preparedness. While teacher workload and preparedness were the factors that were found in both national and international literature as a barrier to effective STEM education (see Margot and Kettler, 2019; Eroğlu & Bektaş, 2016; Özcan & Koştur, 2018), the high school entrance exams as a barrier were specific to the Turkish education system. For instance, Eroğlu and Bektaş (2016) reported that science teachers were not feeling ready to teach STEM activities in their classrooms. High school entrance exams were also frequently found as a barrier to effective STEM education in literature (e.g., Atalay & Öner Armağan, 2023). One last barrier in this theme was the content of science courses. Teachers believed that the contents covered in the science curriculum were intensive. Indeed, the literature exploring possible barriers reported that teachers believed that there is a mismatch between STEM activities and the science curriculum (Özcan & Koştur, 2018). This finding actually supports our finding as teachers in our study usually stated that there were too many topics that need to be covered in science courses that do not match with STEM education. Supporting this Margot and Kettler (2019) also reported that science teachers frequently encountered curriculum challenges while teaching STEM activities.

Teachers in this study indicated the existence of school structure-related barriers such as insufficient material/resources, insufficient technology infrastructure, and class size. This finding is consistent with the literature reporting barriers to STEM education. Insufficient material and resources were the most common barriers found in the literature (Atalay & Öner Armağan, 2023; Bakırcı & Kutlu, 2018; Doğan & Saraçoğlu, 2019; Eroğlu & Bektaş, 2016; Özcan & Koştur, 2018; Timur & İnançlı, 2018). This kind of barrier is also evident in some other international studies (Bell, 2016; el-Deghaidy & Mansour, 2015; Laksmiwati et al., 2019; Margot & Kettler, 2019). Insufficient technology infrastructure including internet connection, and lack of technicians was the second commonly stated barrier. This finding was supported by relevant literature (Atalay & Öner Armağan, 2023; Bakırcı & Kutlu, 2018). For instance, Bakırcı and Kutlu (2018) found that teachers in their study frequently stated a lack of technology integration while conducting STEM activities. One last barrier revealed in this theme was the classroom size. Supporting our finding, crowded classrooms were reported to be a hindered in the literature (Atalay & Öner Armağan, 2023; Doğan & Saraçoğlu, 2019; Timur & İnançlı, 2018).

This study also revealed two more themes: student-related factors and cultural appropriateness as barriers to effective STEM education. Supporting this, literature reported that student-related factors (Eroğlu & Bektaş, 2016). We revealed some teachers indicated that family involvement can be a barrier to effective STEM education. The national literature exploring science teachers' perceptions did not report family involvement (Atalay & Öner Armağan, 2023; Bakırcı & Kutlu, 2018; Doğan & Saraçoğlu, 2019; Eroğlu & Bektaş, 2016; Özcan & Koştur, 2018; Timur & İnançlı, 2018). However, a recent literature review by Gülhan (2023) explored parental involvement in STEM education. The study revealed that most studies were conducted in the USA and yielded positive outcomes for students. This finding of Gülhan (2023)'s study partially supports why teachers in our study reported family involvement as a barrier. It might be the reason why other studies exploring teachers' perceptions did not reveal family involvement as barrier to effective STEM education. Cultural appropriateness was theme found in our study (Özcan & Koştur, 2018). As STEM education mainly developed in the US and later became an agenda for many countries (Blackley & Howell, 2016), some teachers stated it could not be appropriate as much intended. Indeed, one study (Özcan & Koştur, 2018) supports our finding. Özcan and Koştur (2018) reported that science teachers indicated that STEM education was implemented in other countries, there however, were problems in its implementation in our country. This finding partially supports that the differences in implementation style might be the reason.

Recommendations, Limitations, and Future Research

Our study revealed important clues about science teachers' perceptions of STEM education, its applicability, its benefits, and the potential barriers to effective STEM education. While the findings of this study primarily express the need to support teachers' readiness to implement STEM education, there is also room for fundamental changes in school structure and system. Event though this study was conducted with a small number of teachers, our teachers were working in different schools (village schools, low socioeconomic schools, and suburban schools). Thus, we were able to get an depth view of what different teachers coming from different schools think about STEM education and its applicability. One effort to extend the current study's findings could be increasing the number of participants from different regions of Türkiye. We already tried to cover this but reaching 10 teachers might be not sufficient to get a wider perspective. Another effort could be designing PDs for science teachers as teachers in our study frequently stated the need of teacher preparation. Indeed, if the teachers could able to join PDs, they could develop their skills to effective STEM integration. However, the high school entrance exams still stand a major structural barrier to effective STEM implementation in Türkiye.

Ethics and Conflict of Interest

During the research process, all instructions stated within the scope of "Higher Education Institutions Scientific Research and Publication Ethics Directive" were followed. In this study, the actions stated under the heading "Actions against Scientific Research and Publication Ethics" were carefully avoided and no actions stated as contrary were carried out. No potential conflict of interest was reported by the author(s).

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