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Research Article

Teachers' views on assessment and evaluation methods in STEM education: A science course example

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There have been significant advances in science and technology in recent years. Therefore, all countries need qualified people who can take on the challenges of life today and compete in the international arena. This has led countries to adopt new approaches to education. STEM education is one of the latest examples of those approaches. This study investigated science teachers' views on assessment and evaluation methods in STEM education. The study adopted a phenomenology design. The sample consisted of 22 science teachers from public or private schools in different provinces in Turkey in the 2021-2022 academic year. All participants were experienced in STEM education. Data were collected using a semi-structured interview questionnaire developed by the researchers. The study had two significant results. First, participants used process- and outcome-oriented methods to evaluate STEM education. Second, they made some errors and faced some challenges in evaluating STEM education. However, those errors and challenges were of teacher or education system origin. Therefore, schools should provide teachers with in-service training on assessment and evaluation methods in STEM education, and educators should develop different measurement tools to help teachers make fewer errors and overcome the challenges they face in evaluating STEM education.

Keywords: STEM education; Assessment and evaluation; Science teachers

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1. Introduction

Advances in science and technology have paved the way for new educational approaches and methods, one of the latest examples of which is STEM education. STEM is an interdisciplinary educational approach integrating four fields: science, technology, engineering, and mathematics (Gonzalez & Kuenzi, 2012). Moore, Mathis et al. (2014) define integrated STEM education as "an effort to combine some or all of the four disciplines of science, technology, engineering, and mathematics into one class, unit, or lesson that is based on connections between the subjects and real-world problems" (p. 38). In other words, STEM education is a multi-disciplinary approach that integrates science, technology, engineering, and mathematics into a single curriculum or combines them based on overlapping subjects (Karakaya, 2021; Morrison & Bartlett, 2009). STEM

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education teaches students to put theory into practice to solve real-world problems (Moore, Stohlmann et al. (2014)). As described by Kelley and Knowles (2016) integrated STEM education focuses on students' use of disciplinary practices and the applications of STEM content through an authentic context (p.3).

STEM education is a holistic approach that helps countries develop students into qualified people with 21st-century skills (Kim & Choi, 2012). STEM education helps to develop students 'interest and readiness' to learn science, technology, engineering, and mathematics (Thomasian, 2011). It also helps teachers develop more positive attitudes towards science teaching (Pringle et al., 2017). According to Daugherty et al. (2014), teachers who implement integrated STEM education are more likely to provide interactive experiences instead of traditional lectures and support their students' development as self-confident individuals. Integrated STEM education also helps students create original content, put theory into practice, and acquire professional skills (Fırat, 2020). In this sense, STEM education can be beneficial in transforming students into individuals who have a competitive advantage in the fields of health, education, technology, politics, culture and art (Asunda, 2014). For example, investments and improvements in STEM education in the United States are believed to be the key to its global economic success (Department of Commerce, 2012; National Academy of Sciences, 2010).

According to Çepni (2018), STEM education is reflected in curricula and country policies as well as international assessments, such as PISA and TIMSS. The results of these international exams reveal the deficiencies of countries in STEM education. Identifying problems and making improvements in STEM education can be achieved by establishing a strong assessment and evaluation system (Saxton, 2014). Potter et al. (2017) emphasized that the assessment and evaluation processes needed for STEM education and activities should reveal the quality of students' performance. According to Fan and Yu (2017), students' higher-order thinking skills and 21st century skills should be the focus of evaluation processes for STEM education. For this reason, assessment and evaluation processes are very important in STEM education.

Research has tended to focus on what teachers think about STEM education (İnançlı & Timur, 2018; Özbilen, 2018; Özcan & Koştur, 2018; Uyar et al., 2021; Yıldırım, 2018) and their awareness of STEM (Abdioğlu et al., 2021; Bakirci & Karisan, 2018; Tekerek & Karakaya, 2018; Watson et al., 2020). However, there is a small body of research on assessment and evaluation in STEM education (Akgündüz, 2018; Akiri et al., 2021; Çepni, 2018; Eroğlu & Bektaş, 2016; Odabaşı, 2018; Saxton et al., 2014; Şardağ et al., 2018; Yıldırım, 2021; Zengin et al., 2020). For example, Akiri et al. (2021) examined how teachers perceived the implementation and evaluation of STEM education. They found that teachers used different teaching methods and assessment techniques in STEM activities with .teachers mostly using tests consisting of open and closed-ended questions, project portfolios, and experiment reports. Yıldırım (2021) found that preschool teachers used rubrics, peer reviews, self-assessment, question and answer, and matching cards to evaluate STEM activities. Odabaşı (2018) argued that teachers can use techniques such as observation, posters, concept maps, rubrics, and peer/self-assessment to evaluate STEM education/activities. Similarly, Akgündüz (2018) argues for the evaluation of STEM education through peer assessment, self-assessment, and teacher-guided questions. Zengin et al. (2020) addressed the assessment and evaluation methods in the academic studies on STEM published in the last five years in Turkey. They reported that assessment and evaluation methods generally focused on testing variables and evaluating classroom activities. They also indicated that teachers have difficulty evaluating STEM activities because they misuse measurement tools and have limited access to different tools. Saxton et al. (2014) aimed to map the conceptual structure of a standard measurement system for STEM education. They developed "A Common Measurement System for K-12 STEM education," to assessing a broad spectrum of variables from student learning to teacher performance. They concluded that the shortage of measurement tools and evaluation methodologies is the most significant problem in STEM education. Similarly Özbilen (2018) found that school administrator' attitudes, teacher competencies, and lack of practical examples prevented teachers from putting

STEM models into practice. Eroğlu and Bektaş (2016) also reported that teachers had difficulty implementing STEM-based activities because they did not have enough time, knowledge, and examples.

There remains a need to develop teacher practice-based assessment and evaluation tools to formulate effective, applicable, and valid learning strategies, to identify learning outcomes, and to integrate these processes into STEM education (Ball & Hill, 2009; Hiebert & Gruws, 2007; Lewis, 2005). We need to appropriately measure STEM-related skills in vocational education because they play a key role in striking a balance between supply and demand in education, interpreting efficiency, and selecting students (Korbel, 2016). In addition, proper assessment and evaluation ensures quality education aligned with national policies. For examples in Turkey, the objectives of science lessons aim to "take responsibility for the problems of daily life and to use the knowledge of science, scientific process skills and other life skills in solving these problems" (Ministry of National Education [MoNE], 2018, p.9). Thus, it is stated that assessment and evaluation practices should be carried out with the active participation of teachers and students. For this reason, it is important for the literature to determine the experiences and opinions of science teachers' who implement STEM education. As such, this study aimed to determine science teachers' thoughts about assessment and evaluation methods in STEM education. This study, sought to answer the following question: What are the views of science teachers about assessment and evaluation in STEM education?

2. Method

2.1. Research Design

Qualitative research is defined as "research in which qualitative data collection techniques such as observation, interview and document analysis are used, and a qualitative process is followed to reveal perceptions and events in a natural environment in a realistic and holistic manner" (Yıldırım & Şimşek, 2018, p. 39). In addition, in qualitative research, human perceptions and events are examined in depth with in their natural and social environment, through a holistic perspective that combines different disciplines (Merriam & Grenier, 2019). This qualitative study focused on science teacher's conceptions of assessment and evaluation methods and processes in STEM education.

2.2. Participants

Data was collected from 22 middle schools science teachers with experience in STEM education from public or private schools in different provinces in Turkey during 2021-2022 academic year. Participation was voluntary. Demographic information of the participants is given in Table 1.

Table 1
Demographic information of the participants

Demographic information		*N*	*%*
Gender	Female	12	54.5
	Male	10	45.5
Level of education	Undergraduate	8	36.4
	Graduate	14	63.6
Professional experience	0-5 years	1	4.5
	6-10 years	3	13.6
	10 years and above	18	81.9
STEM experience	0-1 years	2	9.1
	2-5 years	13	59.1
	6 years and above	7	31.8

2.3. Data Collection

Data were collected using a semi-structured questionnaire developed by the researchers. The questionnaire had two parts. The first part consisted of demographic items. The second part consisted of four questions on participants' views of assessment and evaluation in STEM education. A linguist, an assessment and evaluation expert, a STEM education expert, and a science teacher experienced in STEM education were asked to check the draft questionnaire for validity. The draft was revised and finalized based on this expert feedback. The questions from the questionnaire were as follows:

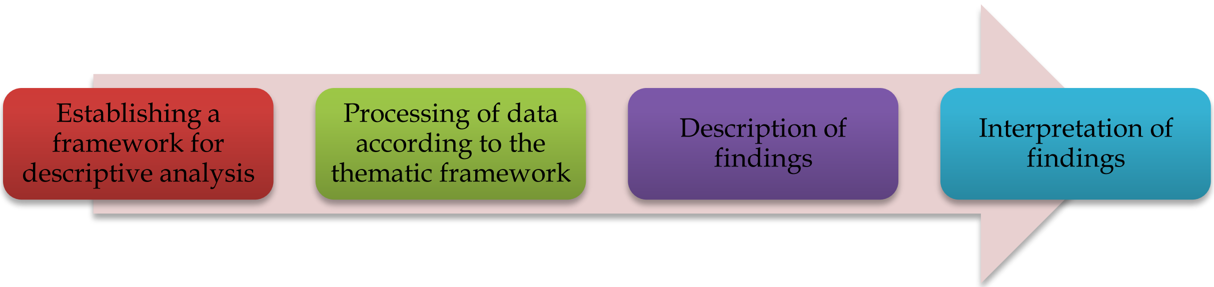
1. Which assessment and evaluation techniques do you use to evaluate your STEM education and activities? Briefly explain the reasons.
2. What kind of difficulties do you experience in the evaluation of STEM education and activities in terms of assessment and evaluation techniques? Briefly explain the reasons.
3. What mistakes do you think are made in terms of assessment and evaluation techniques in the evaluation of STEM education and activities? Briefly explain the reasons.
4. What are your suggestions for STEM education and activities to be qualified (efficient, successful, etc.) in terms of assessment and evaluation? Briefly explain the reasons.

The study was approved by an ethics committee. The questionnaire was prepared on Google Forms and the link to the questionnaire was sent to participants through school administrators.

2.4. Data Analysis

In this study, the data were evaluated using a descriptive analysis technique. In descriptive analysis, participants are quoted to provide an accurate and coherent picture of their views. The data analysis process of the research is given in Figure 1.

Figure 1
Data analysis process



Themes and subthemes were developed based on the study conducted by Zengin et al. (2020). Zengin et al. (2020) stated that assessment and evaluation in STEM education should be categorized as process evaluation and result evaluation. Process evaluation includes semi-structured interviews, design activities and student documents. Result evaluation includes peer assessment tools such as rubrics, project assignments, open-ended questions and true-false questions. In addition, the researchers were open to ideas that were different to the predetermined themes. In the data analysis, the views of some science teachers were evaluated in more than one different theme. Two different coders evaluated the data to ensure internal reliability-consistency. Interpreter reliability was calculated using the formula [Reliability = (number of agreements) / (number of agreements + number of disagreements)*100] suggested by Miles and Huberman (1994). Reliability consistency value was calculated as 93%. In addition, some answer forms were randomly selected and analyzed by a different expert in assessment and evaluation to avoid data bias. Afterward, the coders and the expert discussed the parts on which they disagreed and reached a consensus. In addition, direct quotations were used to provide an accurate and coherent picture of participants' views.

3. Findings

3.1. Methods and techniques used in evaluating STEM education/activities

Within the scope of the research, the methods and techniques used by science teachers when evaluating STEM education/activities were examined. The assessment methods and techniques used by science teachers are summarized in Table 2.

Table 2
Methods/techniques used in the evaluation of STEM education/activities

Theme	*Sub-theme*	*f*
Method	Result Evaluation	16
	Process Evaluation	9
Technique	Rubric	10
	Portfolio-Project	6
	Peer/Self-assessment	5
	Achievement test	3
	Observation form	3
	STEM scales (attitude, awareness, etc.)	2
	Test-Fill in the Blanks	1
	Checklist (peer review list etc.)	1
	Open-ended questions	1

When the findings in Table 2 were examined, it was determined that science teachers evaluated STEM education/activities as result (f=16) and process (f=9). Science teachers stated that the results are important in the evaluation of STEM activities, so they use result-oriented techniques (such as achievement testing). For example, S-21 stated

> I use self and peer evaluation forms to evaluate the stage and process. Because self-evaluation improves self-evaluation capacity, while peer-assessment develops empathy and increases objective observation ability. We develop critical thinking (Result).

However, some science teachers emphasized that the process in STEM activities should be examined in detail and evaluated according to the performance of their students. This is illustrated with the following quotes:

> S-2: In the evaluation of activities, I try to prefer methods such as portfolios and discussions, where my students can evaluate the performance in the process, and methods where I can provide detailed feedback, rather than the classical measurement methods, multiple choices, short answer methods (Process).

> S-6: Generally, if I am doing engineering applications, I use rubrics related to product evaluation. When I use rubrics, I can score more easily and give easy feedback to students. I also use a checklist for participation and interest in course selection (Result).

> S-10: Observation. Because I can better understand what they think they can do (Process).

In addition, it was determined that science teachers used different techniques (for example, rubric (f=10), portfolio-project (f=6), peer/self-assessment (f=5), achievement test (f=3), observation (f=3), scale (f=2), test-fill-in-the-blank (f=1), check list (f=1) and open-ended questions (f=1)) in the evaluation process of STEM activities. Teachers stated that they could make objective evaluations using criteria in rubric. This is illustrated with the following teacher quotes:

> S-1: I use Rubric, achievement test, attitude scale, awareness scale (Rubric/Scales/Achievement test).

> S-6: Generally, if I am doing engineering applications, I use rubrics related to product evaluation. When I use rubrics, I can score more easily and give easy feedback to students. I also use a checklist for participation and interest in course selection (Rubric/Checklist).

> S-19: We focus more on process evaluation and for this we use analytical rubrics and observation forms (Rubric /Observation form).

In addition, it was determined that teachers are of the opinion that they can evaluate the students' process by using techniques such as portfolio. Sample opinions of science teachers are given below:

> S-2: In the evaluation of activities, I try to prefer methods such as portfolios and discussions, where my students can evaluate their performance in the process, and methods where I can provide detailed feedback, rather than multiple choices, short answer methods, which are classical measurement methods (Rubric/Portfolio).
>
> S-13: I use a product selection file for performance evaluation (Portfolio).

3.2. Difficulties in evaluating STEM education/activities

The difficulties faced by science teachers in the evaluation of STEM activities are provided in Table 3.

Table 3
Difficulties encountered in the evaluation processes of STEM education/activities

Category	*Theme*	*Sub-theme*	*f*
Difficulties	Originating from the teacher	Pedagogical deficiency	10
	Originating from the education system.	Lack of suitable measuring tool	6
		Time	6
		Legal requirements	1
No difficulties	No difficulties experienced	Process-based assessment	2

When the findings in Table 3 were examined, it was determined that the difficulties faced by science teachers in the evaluation processes of STEM activities were viewed as being related to the teacher (f=10) and the education system (f=13). It was determined that there were two science teachers who did not experience difficulties process-based evaluation in STEM education. For example S-7 stated,

> S-7: I do not experience any difficulties. Because I am making a process-based assessment (No difficulties experienced).

Some science teachers stated that they did not have sufficient pedagogical knowledge about assessment and evaluation. This is illustrated with the following quotes:

> S-2: As teachers, I think that we, as teachers, have deficiencies in assessment and evaluation techniques. Not paying enough attention to assessment and evaluation in both undergraduate and professional development is an important factor (Originating from the teacher).
>
> S-12: It is a qualitative observation. I have difficulty in establishing objective criteria (Originating from the teacher).

Other science teachers emphasized that different measurement tools (such as achievement test, rubric) that can be used in the assessment and evaluation processes of STEM activities are not at a sufficient level. In addition, it was stated by the teachers that they had problems with time management in the assessment and evaluation processing. Sample opinions of science teachers related to problems within the system are given below:

> S-1: Lack of suitable materials and measurement tools (Difficulty arising from the system).
>
> S-16: We can say that there are legal difficulties. The regulations set a limit on evaluation. The rules within these limits make it difficult to measure and evaluate the STEM approach, which requires creativity (Legal requirements).
>
> S-19: I can say that the course time is not enough for more evaluation (Time).

3.3 Errors made in terms of assessment and evaluation techniques

In the study, the views of science teachers about the mistakes made in the evaluation processes of STEM education and activities were determined. The findings are given in Table 4.

Table 4
Mistakes made in the evaluation processes of STEM education/activities

Category	*Theme*	*Sub-theme*	*f*
Error	Process management	Objectivity	1
	Assessment and evaluation	Method- Technique	16
		Planning	4
		Measuring tool	2
No error	No error	Other	1

When the findings in Table 4 were examined, science teachers stated that the mistakes made in the evaluation processes of STEM education/activities were caused by process management (f=1) and issues with assessment and evaluation (f=16). Science teachers stated that mistakes were made due to reasons such as not using the correct measurement tool, not knowing the method and technique, and not being able to manage the processes. Sample opinions of science teachers are given below:

> S-1: I think that the correct measurement tool was not used in the process and the scales were not suitable for sampling (Assessment tool).
>
> S-2: STEM activities cover a process and the process needs to be evaluated in detail. Unfortunately, we try to evaluate the outcome and process instead of formative evaluation. We do not apply evaluation techniques suitable for our biggest error activity or we do not have the knowledge and skills in this regard (Method-Technical).
>
> S-16: I find it wrong to evaluate the STEM approach in a multiple-choice way contrary to its nature. Scale evaluation for remembering only reduces the value of this approach (Assessment tool/Method-Technique).
>
> S-20: Not being objective in the evaluation (Objectivity).
>
> S-22: A separate planning and orientation study should be done on this subject (Planning).

3.4. Recommendations for successful evaluation of STEM education/activities

The science teachers were provided various suggestions to assist in making assessment STEM education/activities more successful. Their findings are provided in Table 5.

Table 5
Suggestions for evaluation processes of STEM education/activities

Theme	*Sub-theme*	*f*
Planning	Students	6
	Development of activities	2
	Time	3
Implementation	Development of measurement tools	7
	Conducting trainings	6
	Evaluation of the process	4
Other	Other	1

When the findings given in Table 5 were examined, science teachers made some suggestions in order to be qualified (efficient, successful, etc.) in terms of measurement and evaluation. These recommendations are included under the headings of planning (f=11), implementation (f=17) and other (f=1). Science teachers emphasized that pedagogical training and the development of measurement tools is necessary. Some sample quotes include:

> S-1: Having training on measurement and evaluation. More activity-oriented rubrics need to be developed (Conducting the trainings/Developing assessment tools).
>
> S-15: Each STEM learning scenario should have its own rubric. This should be done by the person who prepares the activity and determines the achievements and learning outcomes (Development of measurement tools).

Additionally, teachers stated that activities should be developed in order to be successful in assessment and evaluation of STEM education and activities. Sample opinions of science teachers are given below:

> S-4: It is necessary to have a variety of activities. It is important to be able to access all kinds of information activities (Development of activities).
>
> S-6: We have a serious problem with time. By increasing the number of course hours, skills and scientific inquiry-based courses such as STEM should be given importance in schools (Time).
>
> S-8: More emphasis should be placed on the part of the target aimed at meeting the student's needs (Student).

4. Discussion and Conclusion

This study determined science teachers' views of assessment and evaluation methods in STEM education. First, we focused on the assessment and evaluation techniques used by the participants. Participants stated that they used both process- and outcome-oriented assessments and evaluation methods. They also noted that they used different techniques, such as rubrics, portfolios-projects, peer/self-assessment, achievement tests, and observation forms to evaluate STEM activities. According to Zengin et al. (2020), assessment and evaluation of STEM education should be both outcome- and process-oriented. In addition, using different methods and techniques for assessment contributes to the STEM education process (Akgündüz, 2018; Zengin et al., 2020). These results indicate that science teacher's assessment decisions are aligned with STEM education research. Research also shows that assessment and evaluation methods, techniques, and tools for STEM education should be both summative and formative (Çepni, 2018; Şardağ et al., 2018). Our results are consistent with the literature that report on teachers assessment approaches to STEM education (e.g., Akiri et al., 2021; Akgunduz, 2018; Odabasi, 2018; Yildirim, 2021).

Second, we investigated the challenges participants faced during the evaluation of STEM activities. These challenges originated from both the teacher and the system. Science teachers stated that they experienced systemic problems due to time and legal obligations. Individually, it was concluded that mistakes were made in terms of pedagogical deficiencies, lack of appropriate measurement tools, objectivity, inability to determine the correct assessment methods, and planning. These results indicate that science teachers face different kinds of problems when evaluating STEM activities. Our results are consistent with the literature that shows teachers struggle to assess STEM activities because of lack of knowledge and limited access to measurement tools (e.g., Eroğlu & Bektaş, 2016; Özbilen, 2018; Saxton et al., 2014; Zengin et al., 2020).

Third, we focused on science teachers' recommendations for improving the quality of assessment and evaluation methods for STEM education. Science teachers stated that in order for STEM education to be of high quality in terms of measurement and evaluation, it is necessary to develop activities, organize education, develop measurement tools, and make time and student-oriented planning. Therefore, governments and researchers should take measures to help teachers overcome the challenges related to assessment and evaluation in STEM education and improve planning and implementation processes for more accurate measurement. A coherent planning and implementation system is necessary to ensure that assessment and evaluation methods for STEM education are effective (Odabaşı, 2018; Zengin et al., 2020). Assessment and evaluation should be carried out holistically because STEM education has a multidimensional structure (Çepni, 2018; National Research Council, 2014). Given the impacts of STEM education on the economy, society, and individuals, we should develop new evaluation, research, and measurement approaches to overcome these difficulties (Saxton et al., 2014). According to Pianta and Hamre (2009), we need more evidence and assessment tools to make STEM education more effective. We also need teachers with pedagogical knowledge and alternative measurement tools to measure students' cognitive, affective, or psychomotor skills in STEM education.

5. Implications

Evaluation of STEM activities needs to be aligned with the literature. Teachers stated that they have inadequacies in both the realization of STEM activities and the measurement methods and techniques of the process. For this reason, it would be beneficial for both teachers and pre-service teachers to be trained for this purpose by experts in the field.

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