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Assessment of STEM Projects: Tacit Perspective of Turkish Science Education

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ABSTRACT

With the worldwide spread of STEM education, which is considered as one of the most important developments of the 21st century in the field of education, the question of how to assess STEM education activities has emerged. In STEM education, where many interdisciplinary learning outcomes are applied together and where the learning process is more important, it is natural for the traditional summative assessment methods to lose their validity. In Turkey, the 2018 science course curriculum was updated with the components of STEM education and the importance of process assessment was emphasized, but there is no detailed explanation given on how to do it. However, formative assessment was discussed in detail in an earlier Turkish science curriculum. In this article, discussion is presented on how to use formative assessment in STEM education with the aid of 2005 Turkish science curriculum together with examples from various resources.

Keywords: Formative assessment, Science curriculum, Science teachers, STEM education, STEM projects

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INTRODUCTION

Scientific knowledge can be replaced by new knowledge over time. Change frequently manifests itself also in educational sciences, and both in curricula worldwide and in academic studies, it can be witnessed how fast knowledge can change. The needs of the countries, the results of academic studies, new teaching approaches emerging in the world and many other variables affect each other mutually, and as a result, change is inevitable.

Scientific literacy is an important educational aim in all over the world. It has been almost two decades when Turkey aimed scientific literacy for all individuals. With the 2005 science and technology course curriculum (MoNE, 2005), in which important reforms were made on science courses, scientific literacy officially centered on the science education and the subsequent science curricula have implemented and maintained the similar perspective in 2013 (MoNE, 2013) and 2018 (MoNE, 2018). Although the understanding of scientific literacy is maintained, the ways to achieve this goal are developing continuously.

Science-Technology-Engineering-Mathematics (STEM) education approach, which is one of the most important subjects in the field of education in recent years (Land, 2013), contains many different teaching perspectives. Although it does not have a single definition and application method, it has been highly adopted by the education community and has yielded positive results. This interest was also reflected in the Turkish science course curriculum. Although the STEM statement was not clearly presented in the curriculum which was initiated in 2018, when the structure of the curriculum is examined, it can be seen that it contains many skills, subjects and concepts related to STEM education. In the curriculum, engineering and design skills were presented as a field on its own while the entrepreneurship was added to the domain of life skills together with the innovative thinking. In addition, they are defined in the science, engineering and entrepreneurial applications section.

Engineering and design skills have been described as an area that includes the ability of students to reach the level of inventing and innovating, creating products with the knowledge and skills they have acquired, and developing strategies on how to add commercial value to these products with an interdisciplinary perspective (MoNE, 2018). In the science, engineering and entrepreneurship applications section, students are expected to identify a need or problem for daily life among the subjects of science, design a product or develop existing products by taking into account criteria on materials, time and cost. The product development process will be carried out in the school environment by using scientific method and scientific process skills, and marketing, advertising and promotion strategies will be established for the product in question in order to develop entrepreneurial skills (MoNE, 2018).

Although STEM education is not limited to the science, technology, engineering and mathematics majors that give it its name, it is associated with and can be applied in various fields. In addition, robotics and coding applications have become an important part of STEM education. In sum, problem and project-based product design is an important aspect of STEM education. Today, many studies have been carried out about STEM education and significant experience has been gained both in the world and in Turkey.

2018 science curriculum was associated with STEM education which depends on problem and project-based product design. In such teaching methods, it is important to consider the process together with the result, and it is not possible to carry out the assessment with traditional methods and techniques. Nevertheless, it is a widely encountered case that teachers choose to assess through traditional methods contrary to the expectations of active learning processes (Akiri et al., 2020). In the science curriculum of 2018 (MoNE, 2018), it is recommended that assessment should be made during the education process and it is also emphasized that summative assessment alone will not be sufficient. Such process based assessment is known as formative assessment. Contrary to the summative approach which is basically assessing the knowledge at the end of a process (El Nagdi & Roehrig, 2022), formative assessments help teachers know if there is a need for reteaching or remediating or if the students already have enough knowledge on the topic (Margot & Kettler, 2019). Moreover, formative assessment has positive effects on motivation and attitudes towards STEM-based education (Jeong et al., 2020). Although assessment in STEM is relatively new research area (Donmez, 2020), summative assessment rather than formative assessment is not a new concept for science education in Turkey. This assessment approach was defined by the science and technology course curriculum of 2005 (MoNE, 2005), in which performance assignment was used and evaluated with rubrics.

Rubrics are important tools in formative assessment and useful in active learning pedagogies in order to measure critical thinking and science process skills together with learning outcomes (Reynders et al., 2020). In addition, self, group and peer assessment methods were presented which can promote learning performance in STEM courses (Wang & Chiang, 2020) have been practiced in Turkish science courses since then.

In order to find an answer to the question of how the assessment in STEM education should be, firstly, the developments in STEM education regarding assessment, followed by the science and technology course curriculum of 2005 in which the formative assessment is emphasized in detail, and the curricula applied subsequently are included in the investigation with the ready-to-use assessment examples.

Related Literature

In order to investigate on the assessment in STEM education, it will be useful to consider the recent developments in the related literature. STEM education has attracted a high level of attention all over the world since the moment it occurred in the literature, and has become very popular in various fields of education. STEM education has also become popular academically. For instance, Tyler-Wood et al. (2010) created two scales, the STEM perception scale and the STEM career interest scale, and conducted their validity and reliability studies. The scales have been developed for use in a wide range of ages; MacPhee and Canetto (2013) compared the academic achievement and self-efficacy levels of individuals studying in STEM fields in terms of variables such as ethnic origin and socio-economic status in their longitudinal study; Brown et al. (2016) compared secondary school students' self-efficacy levels towards STEM, including their interests and perceptions of STEM and different variables such as gender and collaborative work characteristics; Haciomeroglu and Bulut (2016) carried out the adaptation study of the STEM Teaching Intention scale prepared by Lin and Williams (2015) into Turkish. The scale was named Integrated STEM Teaching Orientation Scale of Pre-service Teachers and it was intended for pre-service teachers in the primary school teaching department. In another study Sarakorn et al. (2017) examined the effect of STEM activities on high school students' academic achievement, creative thinking skills and attitudes towards science as a result of 14-hour STEM education and reported that the results showed statistically significant differences.

The general focus of research on assessment in STEM education is on measuring some affective characteristics of STEM. There are few studies on the evaluation of STEM activities, projects and products. The most important resources in this regard are the educational reports of the countries (Howes, et al., 2013; MoNE, 2016; MoNE, 2017; Altunel, 2018) and websites that share STEM-related lesson plans and course contents, which were established to guide teachers (Wiggins, 2015; Jolly, 2016).

Howes et al. (2013) prepared a report on the state of science and mathematics teaching in England, setting strategies for the next 20 years. In the report, the importance of process evaluation was emphasized, and it was stated that students' skills towards entrepreneurial tasks, their ability to work in collaboration and their attitudes should also be included in the evaluation. In order for this kind of assessment and evaluation to be useful, it has been suggested to use innovative assessment methods that can measure more learning outcomes such as e-portfolio, group and peer assessment (Howes et al. 2013). Margot and Kettler (2019) conducted a literature review and analysed 25 studies which examined teachers' perception on STEM integration in education. They reported that teachers indicated that there were lack of quality assessment tools, lack of enough standardized classroom assessments, and lack of formative assessments. In addition, there was a concern on group grading and teachers expressed that they were unsure about grading members separately in a group. Gao et al. (2020) investigated 49 empirical STEM education research articles in terms of interdisciplinary nature and the assessment methods that were used in the research designs. I was seen that although most of the studies were based on engineering design, 8 of them focused on assessing the knowledge alone. Most of the studies lacked assessment on the improvement of student's interdisciplinary understanding or skills. Akiri et al. (2021) investigated 125 Israeli STEM coordinators and teachers' both teaching and assessment methods. Teaching methods included lectures and presentations followed by class discussions and collaborative duties. Tests with open-ended and close-ended questions leaded assessment methods, followed by project portfolios and experiment reports. It was seen that more STEM-specialized participants tended to use formative assessment methods. El Nagdi and Roehrig (2022) compared the ideal assessment methods in STEM education with the actual assessment methods in the classrooms of STEM schools in Egypt through survey and interviews. They concluded that there more effort should be spent in creating formative assessment rubrics in terms of measuring collaboration, communication, critical thinking, problem solving, creativity in order to develop engineering design and 21st century skills.

Literature review shows a need for progress in formative assessment in STEM education. In accordance, this study aims to provide several ready-to-use formative assessment examples some of which were presented in the Turkish former and constructivist initiator science curriculum of 2005.

Assessment Applications Related with the STEM Education Approach

A STEM education report was prepared by the Turkish Ministry of National Education, General Directorate of Innovation and Educational Technologies (MoNE, 2016). In the report, it is stated that measurement tools that can measure the mental processes of students in stages such as research, inquiry, production and making inventions should be developed. In addition, the importance of process assessment and use of rubrics was emphasized (MoNE, 2016).

Following the STEM education report, the General Directorate of Innovation and Educational Technologies of the Turkish Ministry of National Education published a STEM Education Teacher Handbook and made it available to teachers (MoNE, 2017). In the report, it is suggested that techniques such as project plan, resource usage table, time management table, project task distribution chart and weekly activity reports should be used to monitor the process in order to make process evaluation in STEM projects. These reports are similar to the use of portfolios. In addition, a rubric was included under the title of evaluation of the STEM project plans (Table 1).

Table 1. Assessing STEM project plans (MoNE, 2017)

Group Members	Innovation (0-10 points)	Importance (0-10 points)	Solvability (0-10 points)	Applicability (0-10 points)	Suitability (0-10 points)	Total Score
Grand Total Score of the Project						

Altunel (2018), prepared the STEM Education and Turkey: Opportunities and Risks report. The report explained that the general understanding of assessment is based on the classical examination of testing approaches in Turkey and suggested the need to develop alternative assessment methods.

The web site *More than a Worksheet* was established by a teacher to support other teachers. It was stated in the web page that STEM education is not a traditional teaching method and therefore it is not suitable for traditional assessment and evaluation methods (Wiggins, 2015). On this page, teachers are recommended to use creative assessment and evaluation methods such as photographing, portfolio, and diary. In addition, rubrics in Tables 2 and 3 are given as an example for teachers' use:

Table 2. STEM Rubric (Wiggins, 2015)

TASK				
Grading Myself				
	Unsatisfactory Effort (0 points)	Effort Needs Improvement (1 points)	Satisfactory Effort (2 points)	Outstanding Effort (3 points)
I contributed to the team work.				
I exhibited scientific thinking.				
I maintained a positive attitude.				
I completed the building task.				
I reflected on my work.				
Grading My Team				
My team worked well together.				
My team displayed problem-solving skills.				
My team had a positive attitude.				
My team completed the building task.				
My team discussed and reflected on our work.				
Graded by My Teacher				
Student cooperated with team.				
Student exhibited scientific thinking.				
Student maintained a positive attitude.				
Team completed the building task.				
Student reflected on work.				

Table 3. Engineering Learning Scale (Wiggins, 2015)

WHAT TYPE OF ENGINEER ARE YOU?	
4	Thriving Engineer I used critical thinking skills to meet the challenge in a unique and creative way.
3	Growing Engineer I used critical thinking skills to meet the challenge according to the guidelines.
2	Sprouting Engineer I used critical thinking skills to attempt the challenge, and I still have some work to do to meet the challenge.
1	Budding Engineer I am beginning to use critical thinking skills in order to meet challenges, and I need more practice in order to complete this one sufficiently.

Jolly (2016) gave advice on measurement and evaluation in STEM education on the web page named Education Week: Teacher. In the article, which emphasizes the question of the perspective of students and what skills they acquire when using the STEM education method, the following points are summarized for a successful STEM course:

- Choosing real world problems while planning STEM lessons,
- Using the engineering design process in problem solving,
- Asking thought-provoking questions to develop an interdisciplinary perspective,
- Use of self-assessment, group and peer assessment techniques,
- Using communication, creativity and scientific process skills in STEM projects,
- Following the affective characteristics of students such as attitude and self-efficacy,
- To know the properties of project-based learning strategy. (Jolly, 2016)

With the effort to carry out formative assessment in STEM education, along with current developments on the subject, discussion on formative assessment are presented which can be used by practitioners directly or by adapting to their own situation. Many examples that can be used in this way are included in this article. In addition, the Turkish science and technology course curriculum of 2005 was examined. The instructions in the curriculum are works of a large study group of educational researchers and teachers considering needs of the country and the developments in the world. The information given in this section is related to the formative assessment of STEM projects and limited to a certain amount of examples. The accuracy of the adaptation, development or evaluation to be made for the situation in which these samples will be used, is strongly depended on the practitioner.

Assessment Perspective in the Turkish Science and Technology Curriculum of 2005

Assessment according to primary school science and technology curriculum (MoNE, 2005) is determining the learning situation of students and determining the level of achievement of the learning outcomes in the curriculum; providing feedback for meaningful learning; identifying future learning needs; informing parents about children's learning levels; and it should be done for reasons such as following up whether the teaching strategies and curriculum content used are balanced and effective. The curriculum was prepared on the basis of the constructivist teaching approach and student-centered education was preferred instead of teacher-centered, so it was emphasized that alternative approaches should be used in the education and training process compared to traditional assessment and evaluation methods, and it was emphasized that it was necessary to enable multiple assessment in which knowledge, skills and attitudes could be displayed. The measurement and evaluation principles emphasized in the curriculum are shown in Table 4.

Table 4. Assessment Principles in the Turkish Science and Technology Curriculum of 2005 (MoNE, 2005)

Less emphasized	*More emphasized*
Traditional assessment methods	Alternative assessment methods
Assessments independent of teaching and learning	Assessment as part of teaching and learning
Assessment of memorized knowledge	Evaluating meaningful and deeply learned knowledge
Assessing fragmented and unconnected knowledge	Assessing interconnected, well-structured knowledge network
Evaluating scientific knowledge	Assessing scientific understanding and logic
Assessment to learn what the student does not know	Assessment to learn what the student has understood
Assessment activities at the end of the semester	Ongoing assessment activities throughout the semester
Teacher's assessment only	Group assessment and self-assessment with the teacher assessment

In Table 4, the principles of assessment, which are aimed to be emphasized less and more during the implementation of the curriculum, are determined. When these principles are examined, it is seen that a successful evaluation should be a process-oriented, active, sensitive and important mechanism. The curriculum also distinguishes between traditional and alternative measurement and evaluation techniques (Table 5).

Table 5. Traditional and alternative assessment techniques (MoNE, 2005)

Traditional techniques	*Alternative techniques*
Multiple choice tests	Performance evaluation
Right and wrong questions	Student product file (portfolio)
Matching questions	Concept maps
Completion (fill in the blank) questions	Structured grid
Short-answer written exams	Diagnostic branched tree
Long-answer written exams	Word association
Question and answer	Project
	Drama
	Interview
	Written reports
	Demonstration
	Poster
	Group and / or peer assessment
	Self assessment

In the curriculum, it was especially emphasized that alternative assessment and evaluation techniques are important for formative assessment: “Since alternative measurement and evaluation techniques evaluate not only the product but also the learning process, it ensures that students have responsibility for learning and be proud of what they have learned (MoNE, 2005).

In most of the alternative assessment techniques, especially performance evaluation and portfolio, rubrics are used to determine the students' conceptual knowledge or proficiency level in a given task. Rubrics can be used in two ways: holistic and analytical (MoNE, 2005). In the curriculum, it was emphasized that when using these assessment methods, students should express themselves in the best way without suppressing their creativity and ability to produce original thoughts. In addition, assessment rubrics should be shared with students and/or parents when necessary (MoNE, 2005). These explanations show that the process evaluation should be carried out within certain standards and transparency.

Alternative assessment methods are discussed respectively in the curriculum. Methods such as interviews, observations, oral presentations, and projects are discussed briefly. The main purpose of applying various assessment methods together is to ensure that the triangulation, which is frequently used in data collection in scientific research. Using more than one measurement tool with triangulation, fosters to observe a subject from many different angles and increases the validity and reliability of the data obtained (Vanderstoep & Johnston, 2009). In addition, it can be expected that students will develop many skills such as communication, teamwork, problem solving, and critical thinking as a result of making oral presentations individually or as a member included in project groups. In the following sub-sections prioritized assessment methods in the 2005 primary school science and technology curriculum are presented.

Self Assessment

Self-assessment is important for students to discover themselves, to see their strengths and weaknesses, and to see that they are a part of the assessment process. It has been stated that the more individuals experience self assessment, the more they will become more accurate in assessment (MoNE, 2005).

Peer Assessment

Peer evaluation is used for students to assess the work prepared by their friends. Peer assessment contributes to the development of critical thinking skills (MoNE, 2005).

Rubrics

A rubric is a tool developed for scoring a study and consisting of criteria that define performance. The use of this method creates a sense of quality and responsibility based on the pre-determined standards and criteria, makes the time spent for evaluation more efficient and shows students how they are going to be evaluated (MoNE, 2005). In order to develop a rubric according to the curriculum, it is important to determine the purpose for which the rubric will be developed, what to evaluate, the proficiency levels, behaviors and skills, and the distinction between categories clearly. An example to a holistic rubric is given in Table 6. The analytical rubric is used by evaluating the different steps of a study one by one and calculating the total score (MoNE, 2005).

Table 6. Holistic Rubric (as presented in MoNE, 2005)

Score	Criteria
4	The category showing that the subject is well understood, supported with logical reasons, examples are presented by establishing different connections between events, and there are no contradictory explanations.
3	The category that shows that the subject is understood, supported with logical reasons, but insufficient.
2	The category that shows that the subject is largely understood, that the proposed ideas are supported but insufficient, and that there are contradictory explanations in the narrative.
1	The category that shows that the subject is poorly understood and inadequate examples are presented.

Portfolio (Student Product File)

A portfolio is a collection that shows students' efforts, experiences, and reflections related to the desired study. In addition, portfolio is an evaluation method that enables students and their friends, as well as teachers and parents to observe the process of the student. It is aimed to contribute to issues such as developing self-discipline and sense of responsibility, providing sound evidence for evaluation, observing the level of realization of the objectives of the curriculum, and encouraging students to participate in evaluation (MoNE, 2005). There is more information about portfolio including example product files in the reference curriculum.

Performance Assessment

Performance evaluation is a type of homework that is evaluated with rubrics, which results in an observable performance or a tangible product by using the knowledge and skills of the students and their problem-solving skills for daily life. In addition, with effective use of rubrics, a road map will be drawn for the student's performance assignments in which students will be informed of the assessment criteria and the scoring levels (MoNE, 2005).

In the curriculum (MoNE, 2005), concept maps, V-Diagrams, structured grids, diagnostic branched trees, attitude scales and multiple choice tests are explained in detail, apart from the sub-topics explained above. Sample assessment forms presented in the curriculum for various purposes are given below. The first one is a self assessment form which is shown in Table 7.

Table 7. Self Assessment Sample Form - I (MoNE, 2005)

Skills	Scoring levels		
	Always	Sometimes	Never
1. I listened to others and their suggestions.			
2. I followed the instructions.			
3. I encouraged my friends without hurting their feelings.			
4. I have completed my duties.			
5. I asked questions when I did not understand.			
6. I supported group members in their studies.			
7. I used my time wisely during my studies.			
8. I used different materials during my studies.			
9. What did I learn from this activity?			
10. How did I help group members during this activity?			
11. Things I did best during this activity:			
Other comments:			

There is another self assessment form given in the curriculum which includes open-ended questions rather than the mixed form in the first one, shown in Table 8.

Table 8. Self Assessment Sample Form - II (MoNE, 2005)

What did I do in this activity?
What did I learn in this activity?
In which parts of this activity I was successful?
Which parts of this activity were difficult for me?
What did I encounter that I did not expect in this activity?
If I were to do this work again, I would do it this way:

The first group assessment form is presented in Table 9 which contains likert-type statements to be graded by the students.

Table 9. Group Assessment Sample Form - I (MoNE, 2005)

Skills	Scoring Levels				
	Never	Rarely	Sometimes	Often	Always
Group members help each other.					
Group members consider each other's thoughts.					
Each member of the group takes part in the work.					
Group members respect each other's thoughts and efforts.					
Each member of the group discusses in interaction with each other.					
Group members share their results with each other.					
Group members fulfill their individual responsibilities.					
Group members discuss their knowledge with others.					
Group members trust each other.					
Group members encourage each other.					
Group members take care that the right to speak is shared fairly.					
When there are conflicting views in the group, those in the group open them up for discussion.					
Group members form a consensus on the subject they are working on.					
The group works efficiently.					
Group members enjoy working together.					
Other comments:					

The second group assessment form includes statements to be graded from 1 to 5, presented in Table 10.

Table 10. Group Assessment Sample Form II (MoNE, 2005)

Name of the students	Readiness to work	Listening to the others	Sharing responsibilities	Supporting group members	Participating in discussions	Justifying their opinions	Respecting differing opinions	Willingness to take charge	Using time efficiently	Completing assignments	Archiving assignments	Total score
Other comments:												

(Scoring levels: 5 = Excellent, 4 = Good, 3 = Fair, 2 = Acceptable, 1 = Weak; The number of horizontal lines will be increased by the number of students to be evaluated.)

The curriculum also presented a detailed form to assess projects from different aspects which was shown in Table 11.

Table 11. Project Assessment Sample Form (MoNE, 2005)

Skills	Scoring Levels				
	Weak	Acceptable	Fair	Good	Excellent
	1	2	3	4	5
I. PREPARATION PROCESS					
Determining the purpose of the project					
Making a work plan suitable for the project					
Distributing tasks within the group					
Identifying needs					
Gathering information from different sources					
Carrying out the project according to plan					
Performing teamwork					
Carrying out the project work willingly					
SCORE					
II. CONTENT OF THE PROJECT					
Using the language decent and correctly					
Accuracy of information					
Analyzing the collected information					
Making inferences from the information obtained					
Organizing the collected information					

Demonstrate critical thinking skills	
Using your creativity ability	
SCORE	
III. PRESENTATION OF THE PROJECT	
Speaking the language correctly and properly	
Giving satisfactory answers to questions	
Presenting the topic in a way that engages the audience	
Supplementing the presentation with targeted material	
Using fluent language and body language in the presentation	
Completing the presentation in the given time	
Confidence during the presentation	
Presenting with good manners	
SCORE	
TOTAL SCORE	
Comments of the teachers	

(Note: Above 1-5 are degrees. The important thing here is to increase the success of the students to the level of 5 (very good)).

Sample peer assessment form is given in Table 12, which allows group members to evaluate each other in a project.

Table 12. Peer Assessment Sample Form (MoNE, 2005)

	Always			Beginning of the project			End of the project			Never		
Members in my group	Me	Member 1	Member 2	Me	Member 1	Member 2	Me	Member 1	Member 2	Me	Member 1	Member 2
Voluntarily articipates in the activity												
Completes his/her duty on time.												
Collects and presents information from different sources.												
Respects the opinions of her group members.												
Uses positive language when warning her friends.												
Is careful and meticulous when using materials.												
Does not waste materials while using.												

Works clean, tidy and orderly (replaces the tools he/she uses, cleans the dirty ones, etc.).	
Speaks clearly when discussing the results, understands what is being discussed.	

The last sample form was an experiment assessment form which is shown in Table 13. It can be concluded in the form that experiments are highly related with the science process skills in the curriculum.

Table 13. Experiment Assessment Sample Form (MoNE, 2005)

Name of the student	Identifying the research topic	Identifying the dependent variable	Identifying the independent variable	Identifying the controlled variable	Choosing the necessary materials and equipment	Using the appropriate measuring tool	Recording data suitable for the purpose of the	Data processing	Interpretation and inference	Presenting the findings

(The number of horizontal lines will be increased by the number of students to be evaluated)

It can be seen that science and technology curriculum (MoNE, 2005) includes important issues such as performance assignments, process assessment, project, experiment, product assessment, self assessment, group assessment and peer assessment, portfolio which makes this curriculum the most extensive and detailed one among others. 2013 and 2018 science course curricula, which were implemented afterwards, were also prepared with a similar structure and constructivist vision. It is known that the new curricula were prepared on the basis of the 2005 curriculum. Since there is not as much information as in the 2005 curriculum in 2013 and 2018 curricula, current curriculum knowledge will not be sufficient for educators. For this reason, educators should be provided with this information through science teaching courses in faculties, various publications and in-service training.

In the science course curriculum, which started to be implemented in 2013, problems, projects, argumentation, and cooperative learning methods were recommended to use in science teaching (MoNE, 2013).

The assessment approach of the 2013 curriculum is based on process evaluation, similar to the previous curriculum (MoNE, 2013). In the curriculum, it was indicated that the numerical data obtained with traditional measurement tools does not make sense on its own, and it was suggested to use complementary measurement tools and techniques. It is important to evaluate student performance not only with knowledge based assessment but considering about other areas such as skills, affective domain and science-technology-society-environment (STSE) issues, and to include self and peer-assessment methods in the process evaluation. In addition, it has been indicated that technology can also be used to evaluate process and performance (MoNE, 2013). There is no more detailed information about these concepts in the curriculum. Therefore, in order to understand the concepts in question, the previous curriculum should be examined.

The teaching strategies and methods adopted in the 2018 curriculum, which is based on problem and project-based product design, are similar to the 2013 curriculum, and the aim of producing input to the economy by integrating science with engineering applications was considered. In the curriculum, it was emphasized that teachers' originality and creativity should be at the forefront instead of the approach explained in the curriculum in order for assessment methods to be effective, and the following principles were included (MoNE, 2018):

- The assessment methods in the curriculum are for guidance only, and technical and academic standards should be followed in the preferences of the practitioners,
- Since the characteristics of individuals such as interests, attitudes, values and success may change over time, the assessment results should not be handled at a single time and seperately, but as a whole, taking into account the changes along with the process followed,
- A student's academic development cannot be assessed with a single method or technique,
- Not only cognitive measurements are sufficient for measurement, but also feelings (affective domain) and skills should be measured,
- Multi-focused assessment should be carried out with the active participation of teachers and students.

As can be inferred from the information given, formative assessment has an important place in Turkish science education. Detailed information on this subject was presented in the 2005 curriculum and summarized in this article. Regarding the question of how assessment should be done in STEM education, the approach of science education curricula to some concepts such as process, performance and product assesment is as explained above. In particular, rubrics, self, peer and group evaluation forms, portfolio, project and experiment evaluation subjects can be developed with the creativity of the practitioners in order to become suitable for use in STEM activities.

Technological Design Cycle

Another noteworthy issue in the 2005 curriculum was the technological design cycle which is a simple problem solving algorithm in product development and material design. As the design concept is highly related with STEM approach, technological design cycle is discussed in this article. The 2005 curriculum included a separate chapter about technological design and it was examined under science-technology-society-environment (STSE) issues with the following learning outcomes (MoNE, 2005):

- Understands that technological design is a process consisting of various stages such as determining the features of the design, making preliminary design and division of labor, making use of model and simulation, trial production and evaluation of the product,

- Realizes that in the development of technological products various types of resources can be used: imagination; creative thinking; culture and traditions; mathematical knowledge; knowledge obtained through science about the natural phenomena; and the ability of people to be aware and to combine knowledge; regardless of their source, facts and materials that may seem completely unrelated at the beginning.

In the 2005 curriculum, there are technological design activities where students are asked to develop technological solutions for a particular problem, which are recommended to be implemented when they deem necessary and students are expected to use the technological design cycle. Technological design cycle steps are presented to be used in these activities and it is stated that educators can apply them flexibly (MoNE, 2005).

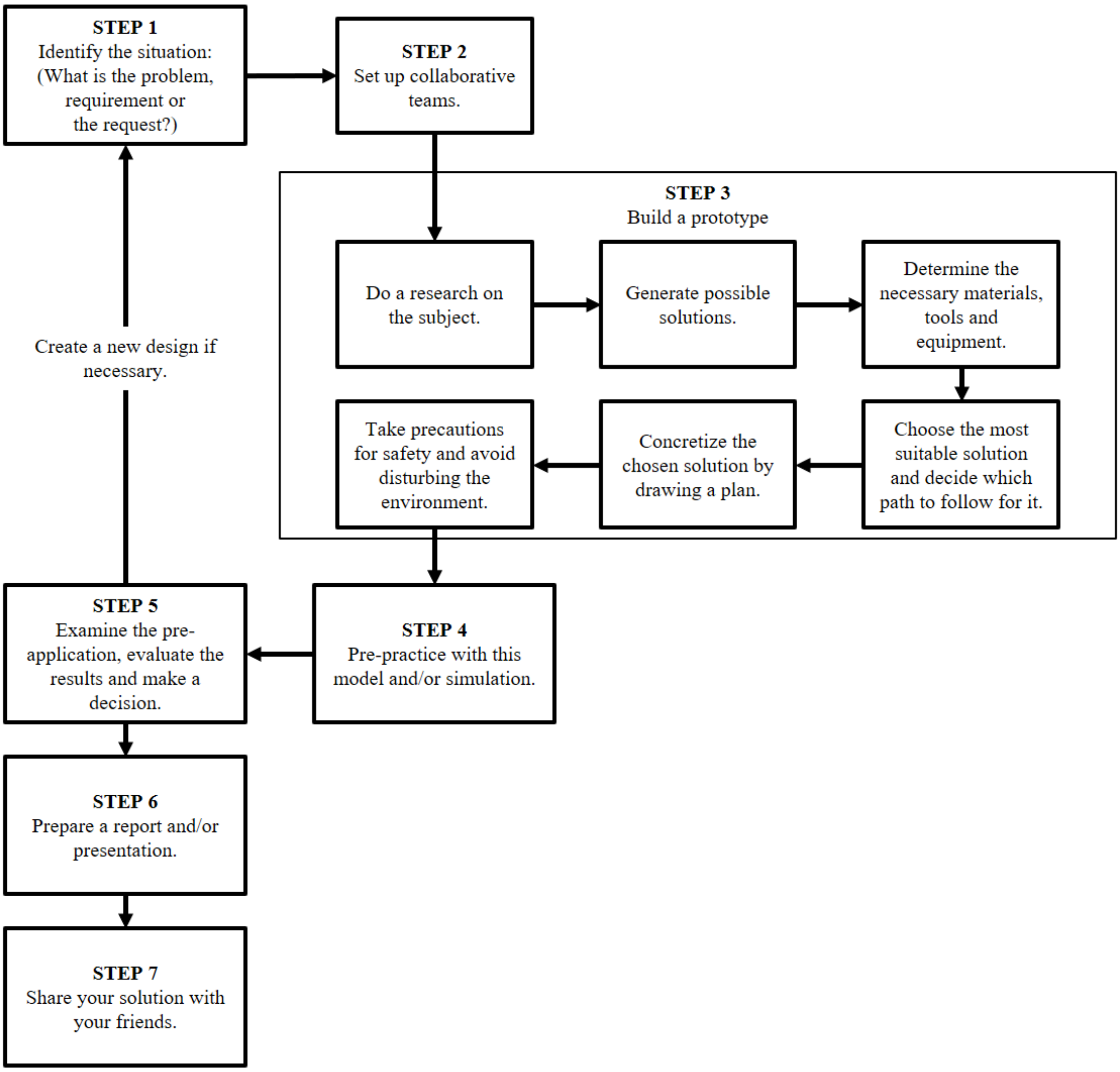

Figure 1. Technological design cycle (MoNE, 2005)

With technological design, students are expected to improve themselves in issues such as problem solving skills, gathering information about the content of the problem, generating ideas and preparing draft drawings related to these ideas, preparing models, designing and developing products, reporting and presenting their work (MoNE, 2005).

When the technological design cycle is examined, it is seen that it is similar to the explanations for product development in the science curriculum that started to be implemented in 2018. As in the applications for STEM education, similar to the technological design applications, it is aimed to take a multi-faceted approach to product design, which is based on problem solving from students' daily lives. Therefore, it would be beneficial for educators to have information about the technological design cycle for their STEM applications. In addition, technological design cycle can also be used for self-assessing of STEM project plans with minor modifications.

Conclusion and Suggestions

In line with the needs of the countries, new skills emerge continuously and they are expected to be taught to students, and as a result, changes are inevitable for the traditional teaching methods. Changes in teaching methods also change the understanding of pedagogy, and the way the lessons are taught and the evaluation of student performance is shaped according to this understanding. In the 21st century, the main duty of teachers is not to teach, but to guide students to solve daily life problems using the scientific method together with developing skills, feelings, and awareness for the STSE issues. Guidance duty is directly related to teachers' abilities and creativity. This can be clearly observed in any curriculum.

From the moment STEM education approach emerged, it has been met with great interest and excitement, and everyday, new answers have been given to the question of how STEM education should be applied. Today, teachers have been presented with a large number of resources that they can use in STEM education and these resources continue expanding. As in every teaching and learning situation, it is necessary to determine whether the method followed is effective or not in STEM education. In other words, it is a necessity to determine how the assessment in STEM approach should be made.

Research emphasize the need for more focus on the assessment strategies in STEM approach (Donmez, 2020; El Nagdi & Roehrig, 2022; Margot & Kettler, 2019). Therefore, this article discusses and seeks answers to the question of how assessment in STEM education should be carried out. The question has been discussed from both national and international perspectives. Current international sources draw attention to the use of techniques such as process evaluation, self-assessment, peer and group evaluation, portfolio and rubrics for a successful assessment in STEM education. These assessment and evaluation techniques are suggested by the current reports (Howes, Kaneva, Swanson, & Williams, 2013; MoNE, 2016; MoNE 2017; Altunel, 2018) and other sources (Wiggins, 2015; Jolly, 2016).

On the other hand, there were reports which were contrary to the formative nature of assessment of STEM education approach. For instance, El Nagdi and Roehrig (2022) found out that most STEM classrooms used traditional assessment systems; Margot and Kettler (2019) discussed a need for more quality curricula which include formative assessment techniques teachers can use to assess their students' conceptual understandings. Turkish former science curriculum (MoNE, 2005) is a good example for such a concerns.

It was seen that how assessment in STEM education should be carried out question found fragments of answers in science and technology course curriculum where assessment was discussed in detail (MoNE, 2005). Therefore, it can be assumed that teachers, who are valuable practitioners and guides, are not far from the assessment methods explained in this article. However, this article is believed to be useful to readers for reasons such as the abolition of the 2005 curriculum since 2013, the fact that teachers who graduated after this date and current teacher candidates, and teachers working in different branches to apply STEM education, which is an interdisciplinary approach, probably do not have enough knowledge about the 2005 curriculum.

The skills and characteristics of the practitioner will play an important role in the direct or adaptive use of the examples given in this section. Formative assessment requires much more attention, motivation and dedication than summative assessment. In order to obtain a high level of efficiency from the assessment, it is important that the practitioners increase their experience in this regard. In addition, as El Nagdi and Roehrig (2022) summarized, elaborating assessment in STEM education should be given more attention in both research and policy levels.

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Consent for Publication

The authors do consent for publication of this work.

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