Investigating middle school mathematics teachers' views on innovative learning activities

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This paper describes a phenomenological study exploring middle school mathematics teachers' views, enablers, and barriers regarding innovative mathematics learning activities by investigating their experiences. The study also aims to determine their suggestions that may lead educational stakeholders to increase the quality of instruction and student learning. Data collected from the interviews and qualitatively analyzed reveal that the enablers mainly were related to receiving support and positive feedback from others. The barriers were associated with time, students' learning habits and classroom learning culture, work environment, and preparing activities. There is a need for providing training and resources for teachers for better mathematics education. Integrating such activities into the curriculum, developing effective training programs, and supporting teachers for successful implementation are the implications based on the findings.

Keywords: Innovative mathematics learning activities, STEM education, mathematical modeling, middle school, teaching practices

Introduction

Today's societies are expecting qualified individuals equipped with 21st-century skills to keep up with the era since technology and information are rapidly produced, developed, changed, and consumed. One of the most crucial factors in achieving the goal of developing individuals with 21st-century skills, identified by educators and economists, is education. However, formal education institutions that mostly use teacher-centered instruction which promotes rote learning and memorization, may negatively affect the need for a qualified workforce and inevitably become insufficient to integrate real-life into the instruction (Akgündüz et al., 2015). In other words, traditional educational practices are insufficient and ineffective to raise individuals as required by the 21st-century (Borich, 2017). As a result of the rapid changes in the globalizing world based on technology, business, and industry, countries have been forced to implement innovative policies in their educational systems as an inevitable result of the change.

There are many approaches in which 21st-century skills can be targetted, including inquiry-based learning, discovery learning, problem-based learning, project-based learning, technology-assisted learning (Westwood, 2008), and STEM education (Barakos, Lujan & Strang, 2012) in the educational literature. The theoretical and practical background of problem-based learning (Hung, Jonassen & Liu, 2008), project-based learning (Condliffe et al., 2017), and STEM education (National Research Council [NRC], 2010) may help students to become skillful at critical thinking, collaboration, communication, creativity, productivity and problem-solving for being up-to-date, having scientific and technological literacy and living in 21st-century.

There is a need for research studies that examine the applicability, strengths, and disadvantages of the activities related to STEM education or mathematical modeling in schools. Approaches that aim to enhance 21-st century skills of students have been implemented by some Turkish middle school teachers. In this regard, exploring their experiences and perspectives by focusing on the enablers and barriers they faced while implementing such activities may provide insights for designing future professional development efforts in many other contexts. Therefore, the current research was designed to investigate the views and experiences of middle school mathematics teachers who have some degree of experience in implementing innovative mathematics activities, such as STEM education or mathematical modeling, in their classrooms.

The current study used the term "innovative mathematics activities" as an umbrella term based on literature review and preliminary informal communications with middle school mathematics teachers about their STEM or mathematical modeling activities. Many of the teachers did not name their implementations as STEM or mathematical modeling as given in the literature and there are blurring boundaries between such relatively new approaches in the Turkish context. In this study, this term referred to non-routine educational activities that emphasize the real-life connections of mathematics and integrate mathematics and other disciplines such as science, technology, and engineering to maximize student learning, help them gain positive attitudes towards mathematics, and develop their 21st-century skills. These integrated activities require planning, implementing, and evaluating student-centered innovative mathematics instruction. We used the term "innovative" to refer to *relatively* new methods in mathematics learning activities rather than teachers discovering "new" educational methods. In summary, we use this term to refer to middle school mathematics teachers' all "relatively new" mathematics learning activity implementations related to non-traditional and non-routine educational approaches. In some educational contexts, the term evolved into including only STEM education and mathematical modeling activities since the participants of the study made a connection between innovative mathematics learning activities and them.

The specific research questions of the study were:

- What views do middle school mathematics teachers have for innovative mathematics learning activities they implement?
- What are the enablers and barriers for the innovative mathematics learning activities implemented by middle school mathematics teachers?
- What are the middle school mathematics teachers' suggestions for implementing innovative mathematics learning activities to other educational stakeholders?

Method

We use a phenomenological research design. The thirteen participants of the study were selected through a snowball approach among middle school mathematics teachers who had knowledge and experience about innovative mathematics activities. Three of them were working in public schools, and ten of them were in private schools. All of them -except one- were female. All of them had teaching experience at all grade levels of middle school, including their internships. Their teaching experiences ranged from 2 years to 20 years.

Data were collected through semi-structured interviews. The interview protocol included 19 questions and follow-up questions for some of them. The interviews included questions related to the participant teachers' thoughts about (i) the nature of their mathematics teaching in general, (ii) their implementation processes, including enablers and barriers to their work, and (iii) reflective interpretations about the activities and recommendations for other teachers.

Data were collected in face-to-face and online environments on a volunteer basis. We followed six steps recommended by Lodico and her colleagues (2010) to analyze data. The interviews were transcribed, redacted, and studied. Then they were analyzed utilizing the content analysis method. The similar views, experiences, enablers, barriers, and suggestions about innovative mathematics learning activities under the codes formed by the researchers. The data analysis process was guided by the research questions.

Examples of innovative mathematics learning activities implemented by the participant teachers

The activity implemented by P2 can be given as a representative example of innovative mathematics learning activities. She formed Caretta Caretta Nest Activity for 6th-graders. The activity included designing a nest for caretta caretta to prevent their egg loss by designing a nest for them after searching their sizes and living conditions. The students needed to use their knowledge related to ratio-proportion, area of polygons, and volume of prisms in the design process. The process required considering using the given whole area effectively, creating nests properly, and placing them productively.

Another example is Oil Spill City Activity formed and implemented by P10 in 6th-grades. She asked her students to design barriers to prevent oil spills after an environmental disaster by using their ratio-proportion and area of polygons-related knowledge. She stated that they used saltwater, olive oil, and bottles filled with to represent seawater, oil, and barriers to experiment with the process. She mentioned that her students connect their knowledge on density and ratio-proportion by changing the amount in these materials to stop oil spills by holding barriers at a certain level.

Findings

Teachers' perceptions regarding innovative mathematics education

In the interviews, the participating teachers were asked what they understood of the term "innovative mathematics education." Their descriptions were mostly based on non-traditional educational approaches. They linked it with student-centered instruction, having real-life connections, emphasizing learning by doing and active participation, involving technology use, and being activity-based and interdisciplinary.

Attributes of implemented innovative learning activities

The participants were asked to explain the characteristic features of the innovative mathematics activities they implemented with their students. The teachers mentioned the grade levels they targeted, the mathematics concepts covered, the physical setting, concepts covered from other disciplines, the average duration, how their students work on the activities, their assessment

techniques, and their resources while preparing for the activity. The following table summarizes an overview of the participant teachers' responses to the characteristics of innovative mathematics learning activities.

Table 1: Attributes of innovative mathematics learning activities the teachers implemented

Main Category	Sub-category	Frequency
Grades implemented	5	7
	6	6
	7	4
In-class & out-of-class	In mathematics lesson	8
	In student club	4
	In the "Applications of Mathematics" lesson	1
Mathematics content area	Numbers and operations	9
	Geometry and measurement	7
Related subjects/objectives from other disciplines	Designing a model & modelling	8
	Being able to use educational technology (i.e., Arduino, GeoGebra, Sketchpad, Tinkercad)	8
	Raising (social & environmental) awareness	8
	Optimizing the criteria	6
	Other subjects related to science	4
The average duration of activities	3 class hours	5
	4 class hours	6
	5 class hours	1
	6 class hours	1
Group work	-	13
Means of assessment	Observation	13
	Discussion and questioning	13
	(Student products in response to) Performance task	8
	Peer rating	7
	Teacher-created paper-and-pencil test	5
	Exit card	4
Information sources for teachers	The Internet	12
	Professional development seminars	8
	Books and articles	5

Note. The number of total responses is greater than the number of the participants since they mentioned more than one innovative mathematics learning activity implemented by them, and some teachers' responses include more than one category. So, the frequency represents the number of teachers who point out the given categories. This is valid for the rest of the tables.

Emotion perceptions during innovative mathematics learning activities

Many of the teachers asserted that they have positive emotions such as being satisfied, having fun, motivated, and excited while implementing innovative mathematics learning activities. Almost all of these emotions were related to students' reactions and emotions that were commented as positive by the participants. More explicitly, the participants feel satisfied when their students learn the topics they covered in the activities, and correspondingly when their students feel happy. They felt

themselves as enjoyable teachers and did not get bored during the lessons in which such activities were implemented because of their active role and high interaction with their students compared with their traditional lessons. They are motivated more in the lessons they use such activities because of their students' positive reactions such as excitement, happiness, and active participation. Similarly, - but changing roles with their students- they feel excited when their students are motivated to make an effort to learn and participate during the implementations.

Some participants describe their experiences as exhausting, which depends on their role in these activities. According to interview data, this was not a complaint but more of a description of the nature of the workload these activities had. More specifically, they found that planning and implementing such activities requires more effort than their traditional lessons.

Perceived effects of innovative mathematics learning activities

The teachers explained how they perceive the effects of their activities on students based on their observations and experiences. They interpreted these effects as having positive contributions to change students' attitudes and enhancing their 21st-century skills, affective skills, learning of concepts, and psychomotor skills.

All of the participant teachers argued that the students became more aware of their future professional options, social and environmental issues, and gender issues. The participants believed that their students' attitudes towards participating in mathematics lessons and learning mathematics changed positively. Also, they believed in a positive contribution of innovative mathematics learning activities to their students' 21st-century skills. The specific skills they mentioned include collaboration, communication, problem-solving, critical thinking, researching, creative thinking, and curiosity. The positive effects of these activities were stated as motivation, attention, self-confidence, and a sense of achievement. Almost all of the teachers highlighted the improvement in student learning of the concepts and an increase in students' achievement in mathematics due to the interdisciplinary nature and real-life connection of such activities. Lastly, since the teachers implemented mostly modeling or designing activities, they observed the development of their students' psychomotor skills.

Enablers of providing innovative mathematics learning activities

The teachers explained their enablers by connecting to themselves and other people involved in the educational process. Students, colleagues, school managers, parents, and other people contribute to planning their lessons. The following table presents an overview of the enablers of providing innovative mathematics learning activities.

Table 2: Enablers in the process of innovative mathematics learning activities

Enablers	Frequency
Collaborating with colleagues	10
Receiving support from school management	8
Receiving positive feedback from parents	5
Thinking students' possible questions	5
Receiving positive feedback and reactions from students	4
Talking with an expert from a different profession	3

Barriers in the process of innovative mathematics learning activities

The difficulties or barriers the teachers encountered in the process of innovative mathematics learning activities were grouped under four categories: (i) time, (ii) students' learning habits and classroom learning culture, (iii) work environment, and (iv) preparing activities. The following table summarizes these categories and their sub-categories with the frequencies of the difficulties mentioned.

Table 3: Barriers in the process of innovative mathematics learning activities

Main Category	Sub-category	Frequency
Time	Time constraints for covering the curriculum	10
	Need for teaching to test	6
Students' learning habits and classroom learning culture	Being familiar with teacher-centered instruction	7
	Lack of teamwork experiences	6
	Difficulty in classroom management	5
Work environment	Teachers having too much workload	5
	Lack of equipment for activities	4
	Destructive criticism of colleagues	3
Activity preparation	Difficulty in integrating other disciplines into mathematics	5
	Teachers' lack of knowledge and experience	4
	Difficulty in simplifying complex concepts for students	3

Teachers' suggestions about innovative mathematics learning activities

The participants expressed their suggestions about innovative mathematics learning activities by considering their supporting factors and difficulties. When they were asked what would their recommendations to other teachers be, they mentioned keeping themselves up-to-date, knowing students' characteristics and interests, observing and leading students during the activities, becoming persistent in implementing such activities, implementing the well-known basic activities, getting opinions of others, and learning a foreign language. They suggested that the ministry authorities should simplify the mathematics curriculum, provide training and resources for teachers, and put sample activities in the curriculum. They also mentioned that mathematics teacher educators need to contribute by providing teachers resources and professional development opportunities.

Discussion and implications

The participants stated that student-centered instruction, the real-life connection of mathematics concepts, learning by doing strategies, active participation of students, integration of other disciplines (especially science, technology, engineering, and design) with mathematics, and activity-based learning make their mathematics lessons innovative. Usually, the Turkish middle school mathematics curriculum covers and recommends these approaches in Turkish schools (Ministry of National Education [MoNE], 2018). So, these approaches should not be called innovative. However, the teachers perceived themselves as teaching mathematics out of the ordinary when they implemented

activities related to such approaches. Although these activities are given a place in the curriculum as regular practices at the policy level, they are seen as non-routine and innovative practices by the teachers. Teachers have restricted educational practices in accordance with policies even though these policies include innovative suggestions. So, policymakers should be careful about how national educational policies are perceived and implemented among teachers.

Although the teachers did not explicitly mention any theoretical point of view, their descriptions and implementations can be interpreted in line with the constructivist and constructionist learning theories, related to STEM and mathematical modeling approaches. It can also be argued that most of the teachers' perceptions of innovative learning activities were in line with the recent rhetoric of STEM education, mathematical modeling, project-based learning, problem-based learning, cooperative learning, or technology-integrated instruction. This indicates that the teachers were up-to-date on the relatively current educational theories and were willing to implement the ideas and approaches in these theories into their classroom practices. It may be because most of the teachers attended professional development seminars and in-service training programs.

The teachers stated one of the most critical factors in maximizing the quality of their activity implementation was their interaction with other people –namely students, colleagues, school managers, parents, and domain experts– who get involved in the activities from beginning to the end by sharing their views, comments, knowledge, and experiences. Therefore, teachers need a collaborative mindset for learning to implement such activities. Regarding the barriers to implementing the innovative activities, the findings of the study confirm the other previous studies on STEM and mathematical modeling (Herro & Quigley, 2017; McMullin & Reeve, 2014; Stohlmann, Moore & Roehrig, 2012).

Since the STEM and mathematical modeling integration into mathematics lessons are relatively new for many teachers, it is considered that there is a need for informing educational stakeholders about the integration for better implementation. The findings of the study demonstrated that some enablers such as collaborating with colleagues and professionals from other disciplines, being supported by colleagues and school management, and receiving positive feedback from students and parents make the process of innovative mathematics learning activities easier. These factors enable teachers to implement well-planned STEM and mathematical modeling activities. Correspondingly, teachers should be encouraged to implement their activities by creating a collaborative working environment and taking moral and material supplies. So, professional development opportunities can be designed to increase communication and collaboration between mathematics teachers and others. On the other hand, the current study put forward that teachers get into several barriers while implementing their activities. They primarily focused on the lack of time for planning and implementing the activities due to their workload and requirement of covering the curriculum in regular classes, the lack of students' familiarity with these types of activities, the lack of equipment required in the implementation of these activities, and the lack of knowledge that teachers experienced in STEM and mathematical modeling activities. The authorities can develop strategies to overcome these barriers for better mathematics education by developing policies about teachers' workload, mathematics class hours, and mathematics curriculum by revising them in accordance with STEM and mathematical modeling activities.

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