A PHENOMENOLOGICAL STUDY ON MATHEMATICS TEACHERS HAVING EXPERIENCE WITH INNOVATIVE LEARNING ACTIVITIES: VIEWS, ENABLERS, AND BARRIERS

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I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

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ABSTRACT

A PHENOMENOLOGICAL STUDY ON MATHEMATICS TEACHERS HAVING EXPERIENCE WITH INNOVATIVE LEARNING ACTIVITIES: VIEWS, ENABLERS, AND BARRIERS

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The purpose of the study was to investigate middle school mathematics teachers' views and experiences regarding innovative mathematics learning activities. This study also aimed to determine enablers and barriers in the process of the activities and teachers' suggestions that may lead the educational stakeholders to increase the quality of mathematics instruction and accordingly, student learning. Phenomenological research was conducted with thirteen middle school mathematics teachers who were reached using the snowball sampling method. The participants have both theoretical and practical knowledge about innovative mathematics education and work in public and private schools in different cities in Turkey. The data were collected in the 2018-2019 spring semester through semi-structured interviews. The findings of the current study revealed that the teachers describe innovative mathematics education by linking it with student-centered instruction, real-life connections, learning by doing, active participation, technology use, activity-based teaching, and interdisciplinarity. According to the findings, teachers had positive emotional engagements while implementing innovative mathematics learning activities and perceived the effects of the activities on students as having positive contributions to change students' attitudes towards mathematics learning and enhancing their 21st-century skills, affective skills, learning of concepts, and psychomotor skills. The major findings were related to enablers and barriers to implementing innovative mathematics learning activities. The enablers were stated as collaborating with colleagues, receiving support from school management, receiving positive feedback from parents, thinking about students' possible questions, receiving positive feedback and reactions from students, talking with an expert from a different profession. The barriers were associated with time, students' learning habits and classroom learning culture, work environment, and preparing activities. Barriers related to time were determined as time constraints for covering the curriculum and need for teaching to test; barriers related to students' learning habits and classroom learning culture were determined as being familiar with teacher-centered instruction, lack of teamwork experiences, difficulty in classroom management; barriers related to work environment were determined as having too much workload, lack of equipment for activities, and destructive criticism of colleagues; barriers related to preparing activities were determined as difficulty in integrating other disciplines into mathematics, teachers' lack of knowledge and experience, and difficulty in simplifying complex concepts for students. Lastly, the participants asserted the need for providing training and resources for teachers to ministry and universities for better innovative mathematics education. The implications based on the findings offer some considerations about integrating innovative mathematics learning activities into the curriculum, developing effective training programs, and supporting teachers for successful implementation.

Keywords: Innovative Mathematics Learning Activities, Middle School Mathematics Teachers, Teacher's Views, Enablers, Barriers

ÖZ

YENİLİKÇİ ÖĞRENME ETKİNLİKLERİ HAKKINDA DENEYİM SAHİBİ MATEMATİK ÖĞRETMENLERİ İLE BİR OLGUBİLİM ÇALIŞMASI: GÖRÜŞLER, KOLAYLAŞTIRICILAR VE ENGELLER

Erbasan, Elçin
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Bu çalışmanın amacı, ortaokul matematik öğretmenlerinin yenilikçi matematik etkinlikleri ile ilgili görüş ve deneyimlerinin incelenmesidir. Ayrıca, bu çalışmada eğitim paydaşlarına matematik derslerinin kalitesini ve buna bağlı olarak öğrenci öğrenmelerini arttırmak için yol gösterebilecek yenilikçi matematik etkinlikleri süreci ile ilgili kolaylaştıcılar, engeller ve önerilerin belirlenmesi de amaçlanmıştır. Olgubilim desenindeki araştırmada, kartopu örneklem yöntemi kullanılarak on üç matematik öğretmenine ulaşılmıştır. Yenilikçi matematik eğitimi hakkında bilgi ve deneyim sahibi olan katılımcılar, Türkiye'nin farklı illerinde, özel ve devlet okullarında çalışmaktadır. Çalışmanın verileri, 2018-2019 Eğitim ve Öğretim Yılı Bahar Döneminde yarı yapılandırılmış birebir görüşmeler ile toplanmıştır. Çalışmanın bulguları, öğretmenlerin yenilikçi matematik eğitimini öğrenci merkezli öğretim, gerçek hayat bağlantısı kurma, yaparak-yaşayarak öğrenme, etkin katılım, teknoloji kullanımı, etkinlik temelli öğretim ve disiplinlerarası olma gibi özelliklerle ilişkilendirerek tanımladıklarını ortaya çıkarmıştır. Bulgulara göre, öğretmenler yenilikçi matematik öğrenme etkinliklerini uygularken olumlu duyuşsal bağlılığa sahiptirler ve bu etkinliklerin, öğrencilerin tutumlarını değiştirmede ve 21. yüzyıl becerilerini, duyuşsal becerilerini, kavram öğrenmelerini ve psikomotor becerilerini geliştirmede olumlu etkileri olduğunu düşünmektedirler. Çalışmanın başlıca bulguları, yenilikçi matematik öğrenme etkinliklerini uygulama sürecindeki kolaylaştırıcılar ve engeller ile ilgilidir. Kolaylaştırıcılar, meslektaşlarla işbirliği yapma, okul yönetiminden destek alma, öğrenci ve velilerden olumlu geri bildirim alma, öğrencilerin olası sorularına hazır olma, farklı meslek uzmanlarıyla konuşma olarak belirtilmiştir. Engeller ise zaman, öğrencilerin öğrenme alışkanlıkları ve sınıfın öğrenme kültürü, çalışma ortamı ve etkinlikleri hazırlama ile ilişkilendirilmiştir. Zaman ile ilgili engeller, öğretim programı ve ulusal sınavlara bağlı olarak ortaya çıkan zaman sınırlılığı; öğrencilerin öğrenme alışkanlıkları ve sınıfın öğrenme kültürü ile ilgili engeller, öğretmen merkezli öğretime alışkın olma, kısıtlı grup çalışması deneyimine sahip olma ve bunlara bağlı olarak sınıf yönetiminde zorluk yaşama; çalışma ortamı ile ilgili engeller, iş yükü yoğunluğu, materyal eksikliği ve meslektaşların olumsuz eleştirileri; etkinlikleri hazırlama ile ilgili engeller, diğer disiplinleri matematiğe entegre etmede zorluk, öğretmenlerin bilgi ve deneyim eksikliği ve öğrenciler için anlaşılması güç olan kavramları basitleştirmede zorluk olarak belirlenmiştir. Son olarak, öğretmenler, bakanlığın ve üniversitelerin eğitimler ve kaynaklar sağlamasına ihtiyaçları olduğunu ifade etmişlerdir. Bulgulara dayalı çıkarımlar, yenilikçi matematik etkinliklerini öğretim programına entegre etme, etkili eğitim programları geliştirme ve başarılı uygulamalar için öğretmenleri destekleme konusunda değerlendirmeler sunmaktadır.

Anahtar Kelimeler: Yenilikçi Matematik Etkinlikleri, Ortaokul Matematik Öğretmenleri, Öğretmen Görüşleri, Kolaylaştırıcılar, Engeller

To people who think this study is valuable and worth reading

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TABLE OF CONTENTS

LIST OF TABLES

TABLES

LIST OF FIGURES

FIGURES

LIST OF ABBREVIATIONS

ABBREVIATIONS

GAIMME	Guidelines for Assessment and Instruction in Mathematical Modelling Education
MEA	Model Eliciting Activity
MoNE	Ministry of National Education
NRC	National Research Council
STEM	Science, Technology, Engineering, and Mathematics

CHAPTER 1

INTRODUCTION

In today's information society, technology and information are rapidly produced, developed, changed, and consumed. The societies of the 21st-century are expecting qualified individuals equipped with 21st-century skills to keep up with the era. Educators and economists identify a set of 21st-century skills, including being open to new ideas, responding to changing world conditions, using technology effectively, creative and critical thinking, productivity, problem-solving, communication, and collaboration (Partnership for 21st Century Learning [P21], 2019). One of the most crucial factors in achieving the goal of raising individuals with 21st-century skills is education. However, the need for a qualified workforce is affected negatively by formal education institutions that dominantly use teacher-centered instruction that promote rote learning and memorization and inevitably becomes 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 (Gary, 2017). Therefore, the rapid changes based on technology, economy, and industry in the globalizing world have led countries to use innovative policies in their education systems as an inevitable outcome of the change. The educational policies and most of the instructional approaches that aim to develop students' 21st-century skills have their roots in constructivism (Westwood, 2008). Constructivist theory of learning is highly related to student-centered instructional approaches which require (i) active participation in learning, (ii) intrinsic motivation, (iii) motivating learning materials, (iv) use of real-life situations and problems in contexts, and (v) use of and improvement in related knowledge and skills (Westwood, 2008). According to Baeten, Struyven, and Dochy (2013), in a constructivist learning environment, (i) students should construct their knowledge via their active involvement, (ii) students should explore, implement and interpret their learning to solve given problems and assignments, (iii) teachers should facilitate and guide student learning rather than directing, and (iv) teachers should use authentic, applicable and complex assignments.

In the educational literature, there are various approaches in which 21st-century skills can be targeted, including inquiry-based learning, discovery learning, problem-based learning, project-based learning, technology-assisted learning (Westwood, 2008), and STEM education (Barakos, Lujan & Strang, 2012). 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) provides students an opportunity 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.

Problem-based learning is a student-centered instructional method that requires making decisions and generating strategies to solve ill-defined problems related to real-life by working in groups in order to promote student learning and skills (Hmelo & Evensen, 2000; Hung et al., 2008; Torp & Sage, 2002). Another student-centered instructional method, namely project-based learning, requires active exploration and participation of students to solve authentic problems (Krajcik & Shin, 2014). These methods have advantages like being self-directed, supporting the habit of life-long learning, fostering 21st-century skills, promoting meaningful and deeper learning, and increasing students' motivation (Westwood, 2008).

Another approach, STEM, is the abbreviation of the terms science, technology, engineering, and mathematics. STEM education puts these concepts into practice from pre-school to higher education in in-school or out-school settings (Gonzalez & Kuenzi, 2012). STEM education focuses on interdisciplinary teaching of these concepts in a holistic context rather than in an isolated way (Brown, Brown, Reardon & Merrill, 2011). One purpose of STEM education is equipping students with 21st-century skills to enable them to contribute to their societies' global competitive power in terms of education, economy, and politics (Williams, 2011). STEM education became popular around the world because of its interdisciplinary nature in components science and mathematics and their applications to real-life, namely technology and engineering. These four core concepts are closely related to and spread out real-life as they provide solutions to current and possible problems of societies (Brophy, Klein, Portsmore & Rogers, 2008).

In line with the above-mentioned instructional approaches, one that originated from the field of mathematics education is mathematical modelling. Like all other STEM disciplines, teaching mathematics has also been affected by the changes and trends in education. Teacher educators and teachers have been searching for new ways of teaching and learning mathematics in recent years (Gilat & Amit, 2013). According to Lesh and Doerr (2003), mathematical modelling activities can redefine the innovative mathematics curriculum since they enable students to understand, elaborate, or revise the concepts related to STEM disciplines. Mathematical modelling is the process of describing and interpreting a problem in real-life with mathematical models, which are generalizable and revisable (Berry & Houston, 1995; Lesh & Doerr, 2003). Since using mathematical modelling activities aims to contribute to students' creativity, problem-solving, productivity, and analytical thinking skills and include real-life problems in systematic processes (Lesh & Doerr, 2003), some researchers relate the mathematical modelling approach to the STEM education approach (Kertil & Gürel, 2016).

These new worldwide trends in education with an economic and social background are also influencing the educational debates in Turkey. Therefore, it is essential for researchers and educators to understand them in-depth and adapt or implement them properly in Turkish classrooms (Akgündüz et al., 2015). Although they are debated among educational stakeholders, there are relatively limited research studies about the applicability of the approaches such as STEM education or mathematical modelling in schools, especially in Turkey. There needs for research-based contributions to explore the possibilities or limitations of the activities promoted by the education community in schools of Turkey. Many mathematics teachers have been implementing such approaches to learning in Turkey that potentially develop 21st-century skills in their schools. Their experiences and perspectives based on those experiences are valuable for educational researchers. In this sense, understanding the enablers and barriers the teachers face while implementing such activities may provide valuable insights for future professional development efforts, as well as curriculum improvement studies. Therefore, the current research was designed to investigate the views and experiences of middle school mathematics teachers about innovative mathematics activities, such as STEM education or mathematical modelling.

1.1 Purpose of the Study

The purpose of the study was to investigate middle school mathematics teachers' views and experiences regarding innovative mathematics learning activities. This study also aimed to determine enablers and barriers in the process of innovative mathematics learning activities and teachers' suggestions that may lead the related educational stakeholders to increase the quality of mathematics lessons and, accordingly, student learning.

1.2 Research Questions of the Study

The research questions of the study were given below:

1. What views do middle school mathematics teachers have for innovative mathematics learning activities they implement?
    - What are the descriptions of middle school mathematics teachers for innovative mathematics education?
    - What features do the innovative mathematics learning activities implemented by middle school mathematics teachers have?

- What are the emotional engagements of middle school mathematics teachers while implementing innovative mathematics learning activities?
- What are the perceived effects of innovative mathematics learning activities on students?

2. What are the enablers and barriers for the innovative mathematics learning activities implemented by middle school mathematics teachers?
3. What are the middle school mathematics teachers' suggestions for implementing innovative mathematics learning activities to other educational stakeholders?

1.3 Significance of the Study

Since teachers are critical actors in education, their knowledge, way of teaching, and transfer of knowledge to their students are essential for the development of both individuals and society. Teachers' experiences with innovative activities, such as STEM or mathematical modelling activities in their classes, are considered to be known by educational stakeholders to support and develop them. So, investigating their views and practices related to such learning activities as a first step can be considered as a valuable area of a research study. The results of this study will inform the educational stakeholders, like educational policymakers, teacher educators, school management, teachers, and parents, about the nature of teachers' practices while implementing innovative learning activities. Knowing about teachers' experiences with such activities and the specific enablers and barriers teachers face will let the stakeholders make informed decisions in future professional development studies, as well as in curriculum development projects. For example, educational policymakers such as the Ministry of National Education (MoNE) and teacher educators can develop more informed ideas about improving mathematics curriculum or teacher training programs in the light of the current study. They can collaborate to overcome barriers encountered during innovative mathematics learning activities and support enablers that affect the quality of teachers' implementations positively. The collaboration of educational policymakers might be finalized with curriculum or teacher training reforms to have better classroom settings and maximize student learning outcomes. The current study will also guide teachers who want to implement similar innovative mathematics learning activities by presenting the possible effects of these activities on students, supportive factors that encouraged them to implement these activities, as well as the difficulties encountered. So, they will be able to plan and implement more effective activities by having an opportunity to minimize their difficulties according to the experiences and suggestions of the participant middle school mathematics teachers.

1.4 My Motivation for the Study

When I started my graduate education in 2017, I had some opinions about the subject of my prospective thesis. I want to work with in-service teachers and about their knowledge, views, beliefs, experiences, or difficulties, whatever it is. Although the participants of my study were clear in my mind, I could not decide to focus on one of the before-mentioned subjects related to their teaching. Their pedagogical content knowledge, difficulties -of especially novice ones- in their profession, and their algebraic reasoning skills were my first possible research ideas.

As well as these subjects, I researched other areas that can be considered relatively new in mathematics education, such as mathematical modelling and STEM education. After this research process was over, I noticed that I would like to choose a recent research area in education, and there is a need to make research studies about it.

In those days, I began working in a research center targeted to enhance the quality of (STEM) education in almost all grade levels from kindergarten to university, conduct teacher training programs, and develop innovative educational approaches at the university as a research assistant. Then, I attended many seminars and workshops about new educational approaches. In seminars and workshops for teachers organized by the research center, I had an opportunity to meet with and to observe many in-service teachers interested in new educational approaches, especially STEM education. They mentioned mostly their implementations, difficulties, and questions about it. Also, they emphasized the positive effects of their implementations on their students, the need for integrating STEM activities into lessons. However, they complained about their lack of knowledge and experience about it and the barriers they encountered due to their undergraduate education, students, and curriculum. Thereafter, I talked with my mathematics teacher friends about their STEM education implementations. They stated similar activities, difficulties, and needs about STEM education by also mentioning mathematical modelling activities and giving specific examples. Moreover, they asserted their effort for integrating STEM and mathematical modelling activities into their mathematics instruction and their students' reactions to their "new" teaching style.

I thought that if the views and experiences of middle school mathematics teachers about STEM education and mathematical modelling are known, their feelings of inadequacy may be minimized through reforms in teacher education or in-service teacher training programs. If the effects of STEM and mathematical modelling activities on students are known, it may help mathematics teachers to implement similar activities in their lessons or not according to the contribution of student learning. If the supportive factors that enable them to implement their STEM and mathematical modelling activities more effectively are determined, educational policymakers may work for developing these enablers to enhance the quality of mathematics activities implemented. If the barriers they encountered during STEM and mathematical modelling activities are learned, they may be overcome to reform the STEM education and mathematical modelling practices and thoughts of educational stakeholders such as students, parents, and colleagues. Lastly, if the suggestions of mathematics teachers experienced in STEM and mathematical modelling activities are known, mathematics teachers who want to implement similar activities may benefit from them while integrating the activities in their lessons. Also, educational policymakers may benefit from suggestions emerging from the experiences of the teachers to determine their needs and make changes in teacher training programs and mathematics curriculum. So, all this process brought me to that point, which is researching middle school mathematics teachers' views, implementations, and experiences about STEM education and mathematical modelling activities by taking teachers' descriptions, perceived emotions, enablers, barriers, and suggestions and effects of the activities on students into account.

1.5 Definition of the Important Terms

Problem-based Learning: It is defined as using real-world problems in instruction to maximize student learning and higher-order thinking skills by requiring them to work in groups (Torp & Sage, 2002).

Project-based Learning: It is defined as "a comprehensive approach to classroom teaching and learning that is designed to engage students in the investigation of authentic problems" (Blumenfeld et al., 1991, p. 369)

STEM: It is the abbreviation of science, technology, engineering, and mathematics.

STEM Education: It is defined as teaching knowledge and skills of one discipline, including at least one other STEM discipline, in an integrated way to foster student knowledge and understanding (Çorlu, Capraro & Capraro, 2014), promote their use of technologies (Bybee, 2010).

Mathematical Modelling: It is defined as a process where effective mathematical models are created and developed by using current conceptual systems and models to be able to generalize them to new contexts (Lesh & Doerr, 2003).

Model-Eliciting Activity: It is defined as activities consisting of non-traditional and open-ended real-life problems requiring mathematical modelling processes by mathematizing them (Lesh, Hoover, Hole, Kelly & Post, 2000). The term and mathematical modelling activity are used interchangeably in the current study.

Innovative Mathematics Learning Activities: It can be defined as 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, increase their academic achievement, to provide them to have positive attitudes towards mathematics, and to develop their 21st-century skills. These integrated activities require planning, implementing, and evaluating student-centered innovative mathematics instruction. What is meant here by "innovative" is that including and using "relatively" new methods in mathematics learning activities rather than teachers discovering "new" educational methods. Briefly, it is related to the structure of the activities, not only to the teachers. The researcher uses 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 modelling activities since the participants of the current study made a connection between innovative mathematics learning activities and them. So, after the data analysis, the term can be defined as mathematics learning activities related to STEM education and mathematical modelling.

CHAPTER 2

LITERATURE REVIEW

In this chapter, related literature will be reviewed based on the research questions of the study. Innovative mathematics learning activities mentioned in the research questions were related to a diverse range of instructional approaches, including problem-based learning, project-based learning, STEM education, mathematical modelling, and their practices in educational settings, as mentioned before. In the scope of the current study, it will not be possible and also reasonable to review all of the instructional approaches that may be referred to as innovative. However, this review will focus on the characteristics of the four major approaches, namely problem-based learning, project-based learning, STEM Education, and mathematical modelling.

2.1 Problem-based Learning

Problem-based learning is one of the educational approaches designed for developing individuals' problem-solving skills that have strong connections with constructivism and experiential education (Hmelo & Evensen, 2000; Hmelo-Silver, 2004). The first use of problem-based learning is in medical education to improve medical students' ability and knowledge to diagnose and treat diseases in the 1960s (Hmelo & Evensen, 2000). Then it is adopted in higher education programs such as architecture, business administration, engineering, teacher education, and K-12 education throughout the 1990s (Hung et al., 2008). Problem-based learning is an instructional method in which teachers use open-ended, ill-defined, authentic, interdisciplinary, complex, and real-world problems to foster student learning and higher-order thinking skills by requiring them to solve these problems (Duch, Groh & Allen, 2001; Hmelo & Evensen, 2000; Hmelo-Silver, 2004; Hung et al., 2008;

Kaptan & Korkmaz, 2001; Torp & Sage, 2002). According to Duch (2001), the problems used in problem-based learning should (i) attract students' attention and motivate them to understand and learn the concepts, (ii) encourage students to research about different disciplines and use their knowledge in an interdisciplinary manner, (iii) connect their new learning to prior experiences and knowledge to find solution strategies to real-world problems, (iv) be complex to lead students working in groups effectively by being them responsible for different stages of problem-solving, (v) require students to examine their problem-solving strategies and make reasonable decisions, and (vi) be open-ended to engage students by being able to them discuss their solutions.

In problem-based learning, students work in groups collaboratively to research, analyze and solve the given complex problems and evaluate their solutions (Torp & Sage, 2002) and their critical thinking, analytical thinking, problem-solving, communication, and collaboration skills enhance during the process (Duch et al., 2001; Hmelo-Silver, 2004). Since problem-based learning is a student-centered instructional method, it requires students' active participation and promotes their active learning and life-long learning skills (Hmelo-Silver, 2004). In a similar vein, students research, examine and evaluate the problems during the process in which they need problem-solving, higher-order thinking, metacognitive and reasoning skills, and this lead them to learn how to learn (Torp & Sage, 2002) and how to be self-directed and life-long learners (Hung et al., 2008). So, students' role in problem-based learning can be defined as being responsible for their own learning to develop solutions to ill-defined problems by working in small groups, discussing their possible solution ideas, planning their research process, generating solutions, and presenting their solutions to other groups (Kaptan & Korkmaz, 2001). Moreover, problem-based learning promotes students to become intrinsically motivated to learning (Hmelo-Silver, 2004) and affects their self-perception and self-confidence (Hung et al., 2008), since their active role in the process fosters their interpersonal skills and self-directed learning.

The teacher's role in problem-based learning is different when compared to traditional instructional methods and can be described as a guide since the role of teachers and students is shifted in problem-based learning, and the essential responsibility of learning is given to students (Kaptan & Korkmaz, 2001). Teachers are metacognitive coaches during students' problem-based learning experiences rather than direct instructors. Since "coaching is a process of goal setting, modelling, guiding, facilitating, monitoring, and providing feedback to students to support their active and self-directed thinking and learning" (Torp & Sage, 2002, p. 71), the role of the teacher is still critical. Teachers prepare students for problem-based activities by considering their backgrounds, needs, abilities, and knowledge, managing them in collaborative group works, motivate understanding problems, guide them to generate possible solutions to given problems, encourage them to share their solutions with others, and lead them to think critically about their solution strategies by giving feedbacks (Hung et al., 2008; Kaptan & Korkmaz, 2001; Torp & Sage, 2002).

According to Torp and Sage (2002), problem-based learning consisted of two components, namely problem design and problem implementation, as given below in Figure 2.1 in detail.

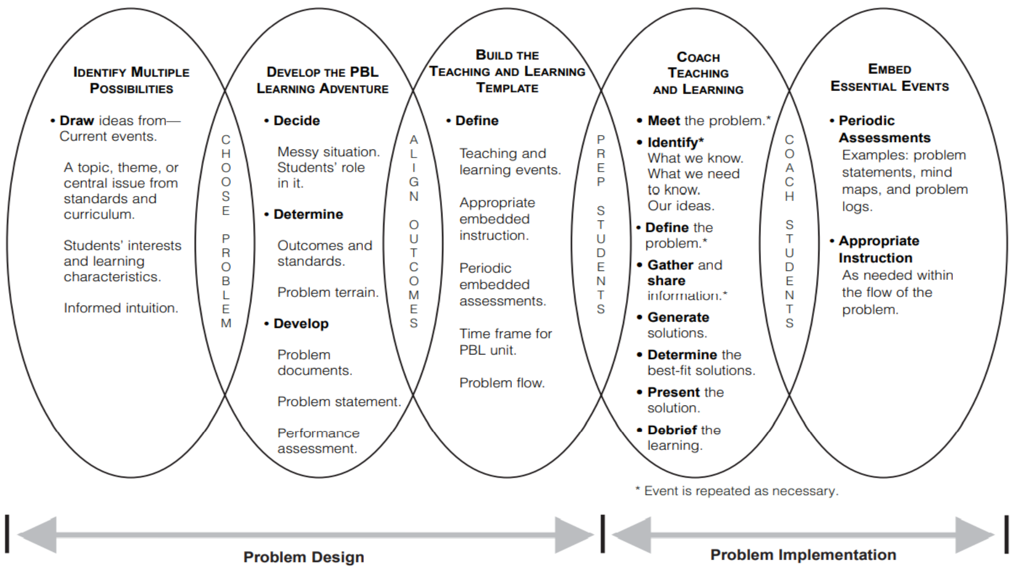

Figure 2.1. The flow of problem-based learning process (Torp & Sage, 2002, p. 50)

The figure explains the role of the teachers and students during problem-based learning. In the problem design process, firstly, teachers should identify possible problems relevant to their students' backgrounds and interests and concepts to be covered. Secondly, they should decide their problem statement and develop a learning environment suitable for their activity by considering students' roles, learning outcomes, related documents, and means of assessment. Thirdly, they should prepare their teaching and learning templates in an instructional manner. In the problem implementation process, teachers should facilitate and assess their students while students should conduct self-directed learning in their groups.

In the literature, there are many benefits and advantages of problem-based learning, such as enhancing students' problem-solving skills, fostering students' self-directed learning skills, leading students to research and use more information sources, increasing students' motivation and interest in lessons and real-life situations, making students to interacting each other and the teacher more, promoting students' communication and collaboration skills, enabling teachers bridge the theory and practice, improving students' flexible thinking skills by requiring adapting their solution strategies and knowledge to the new problems, and encouraging students to become life-long learners (Duch et al., 2001; Hmelo-Silver, 2004; Kaptan & Korkmaz, 2001; Uden & Beaumont, 2006). On the other hand, teachers may encounter some potential barriers and disadvantages while implementing problem-based learning in their lessons. According to Uden and Beaumont (2006), time may be one of the significant disadvantages of problem-based learning since it requires more time in planning and implementation. Teachers may have restrictive schedules that inhibit their time for designing new problems and understanding student engagement (Torp & Sage, 2002). Also, since it requires students to meet, identify and define the problem, gather information about the problem, generate possible solutions, determine the best-fit solution, present their solution strategy, and debriefing the process, implementing problem-based learning takes longer time compared to regular and teacher-centered classes (Kaptan & Korkmaz, 2001; Torp & Sage, 2002). Another barrier may be related to teachers' resistance to change and lack of knowledge and experience about problem-based learning if they find implementing problem-based learning difficult since it requires some skills such as researching for documents, designing activities, and guiding students (Hmelo-Silver, 2004; Kaptan & Korkmaz, 2001; Torp & Sage, 2002). Teachers' workload may be increased due to the intensive problem design process and their facilitator role in problem implementation to lead students to discipline themselves (Uden & Beaumont, 2006). If students cannot discipline themselves to work in groups and are not familiar with student-centered instruction, their learning habits may cause difficulty in classroom management (Torp & Sage, 2002).

2.2 Project-based Learning

Project-based learning is one of the educational approaches designed to involve students in dynamic classroom learning and discussion to learn concepts deeper through active participation and active exploration of given real-world problems (Condliffe et al., 2017). It is originated from progressive education movements that encourage students to be active learners, such as constructivism, scaffolding, inquiry, and situated learning (Korkmaz & Kaptan, 2001; Krajcik & Czerniak, 2018). According to Krajcik and Shin (2014), project-based learning has its roots from four major ideas related to learning sciences: (i) active construction which can be explained as being able to build students meanings of concepts based on their experiences and interactions in the world to have in-depth understanding by constructing new knowledge and connecting their new and prior knowledge, (ii) situated learning which can be explained as learning in authentic and real-world contexts to build knowledge by participating actively to the learning steps such as investigating the real-life situations, generating new ideas and interacting with others about their ideas, (iii) social interactions which can be explained as understanding concepts meaningfully by sharing instructional ideas with teachers and students and debating of these ideas to build shared understanding in educational community members, and (iv) cognitive tools which can be explained as using graphs, computers, software and other instructional materials to promote students' deep learning and meaningful understanding and maximize their learning outcomes.

Project-based learning is defined as "a comprehensive approach to classroom teaching and learning that is designed to engage students in the investigation of authentic problems" by Blumenfeld et al. (1991, p. 369). It is an innovative and alternative approach compared to teacher-centered and traditional instructional methods (Chen & Yang, 2019) and used in business administration, economics, engineering, medicine, and education for many years (Capraro & Slough, 2013). According to Moursund (1999), project-based learning has three critical characteristics, which are being a learner-centered approach, being task-oriented, and using authentic assessment techniques to test students' knowledge and skills in authentic contexts. Project-based learning requires interaction in students and allows them to be independent learners by learning-by-doing, planning, designing, implementing their strategies, and solving real-life problems (Bell, 2010; Krajcik & Shin, 2014). Project-based learning can be confused with problem-based learning or vice versa (Capraro & Slough, 2013; Moursund, 1999). However, they are different from each other. Problem-based learning requires focusing and working on a specific problem, while the broader term project-based learning requires focusing and working on several problems or specific areas rather than problems (Capraro & Slough, 2013; Moursund, 1999). Projects include challenging problems and complex tasks that lead students to decision-making, problem-solving, and design realistic products (Thomas, 2000). Also, Thomas (2000) identified five major characteristics of projects in order to be perceived as an example of project-based learning: (i) centrality, (ii) driving question, (iii) constructive investigations, (iv) autonomy, and (v) realism. Briefly, projects used in project-based learning should be directly related to the curriculum, and they are at the center of the curriculum rather than being peripheral to it. Projects should lead students to work on and learn the main concepts of related disciplines by emphasizing the driving questions or problems. Projects should promote students' involvement in a constructive investigation by transforming, using, and building their new skills and knowledge. Projects should be student-centered, and teachers should create learning environments in which students can take responsibility for their own learning and supervise their time and learning process. Projects should be related to real-life and lead students to develop solution strategies that can be implemented by giving them a feeling of authenticity.

In the literature, it is stated that project-based learning has several key features (Blumenfeld et al., 1991; Krajcik & Czerniak, 2018; Krajcik & Shin, 2014). These are starting the project with a driving question essential for understanding the learning goal of the project-based process, focusing on learning goals to equipped students with basic scientific knowledge and skills, leading students to investigate the driving question, learn and implement important strategies by involving them in scientific practices, encouraging students and teachers to work collaboratively to generate solution ideas and strategies for the driving question, using instructional technologies to be able to students better understanding of the concepts, leading students to create and present tangible products referred to the driving question

In project-based learning, students' role is knowledge gatherer (Capraro & Jones, 2013), and they engage in authentic problems by taking action for their own learning (Condliffe et al., 2017; Krajcik & Shin, 2014). They examine driving questions, propose explanations to the questions, plan their learning, organize their research, discuss their possible solutions, give feedback to other groups, engage in cooperative learning, present their products to others (Bell, 2010; Korkmaz & Kaptan, 2001; Krajcik & Czerniak, 2018; Krajcik & Shin, 2014). Their role in project-based learning enables them to obtain better understanding and learning outcomes, to gain and foster valuable skills needed for 21st-century (Bell, 2010; Krajcik & Shin, 2014), and to prepare for rapid changes in science, technology, and social issues (Krajcik & Czerniak, 2018).

The role of the teacher in project-based learning is different when compared to traditional instructional methods and can be defined as facilitator and guide (Korkmaz & Kaptan, 2001; Krajcik & Czerniak, 2018). Teachers guide students to select the meaningful tasks to be explored, develop driving questions to be helped deeper learning of concepts, and monitor the process by considering students' prior knowledge, interests, experiences, and needs to enable them to scaffold their learning (Krajcik & Czerniak, 2018). Larmer, Mergendoller, and Boss (2015) explained the roles of teachers as facilitators by describing the problem-based teaching process and practices as presented in Figure 2.2 as follows.

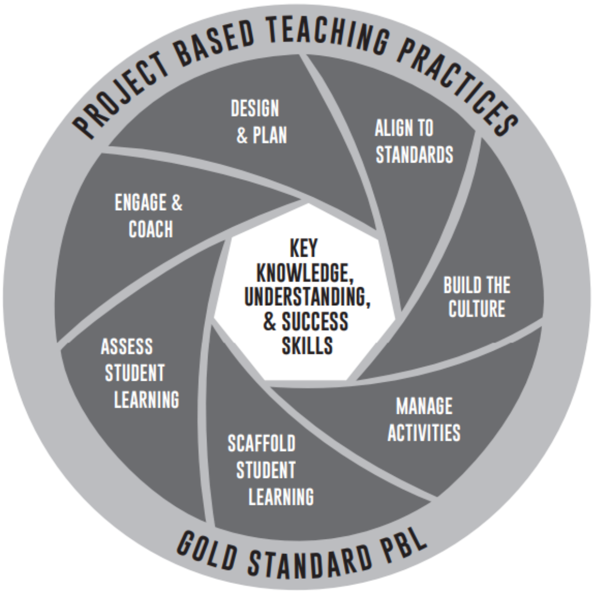

Figure 2.2. Project-based teaching practices (Larmer et al., 2015, p.46)

According to Figure 2.2, teachers design a project and plan its implementation by taking into their students' background, school context, and students' role in the process in design & plan practice. Teachers use curriculum objectives while planning the project-based instruction to ensure addressing critical components of the subject areas. In building the culture practice, teachers build a classroom environment to promote student-centered instruction, collaborative working, and open-ended inquiry. In managing activity practices, teachers help students find and use appropriate resources, organize possible solution strategies, create tangible products, and share them with others. In scaffolding student learning practice, teachers monitor and support students to reach educational goals by using technological tools, manipulatives, and instructional strategies. In assessing student learning practice, teachers use suitable assessment techniques to know about the development of students' skills and academic achievement. In engage and coach practice, teachers engage in student learning, encourage them to implement, and give feedback about their learning.

Lastly, there are many benefits and challenges of project-based learning in the literature. The benefits of project-based learning are motivating students to learn concepts and engage in lessons, preparing students for career and life by enhancing their 21st-century skills such as problem-solving, analytical thinking, creativity, collaboration, critical thinking, promoting students' time management skills, supporting life-long learning, fostering student understanding, maximize learning outcomes, and making connections between real-life and disciplines clear by bridging theory and practice (Bell, 2010; Condliffe et al., 2017; Korkmaz & Kaptan, 2001; Krajcik & Czerniak, 2018; Larmer et al., 2015; Moursund, 1999; Tamim & Grant, 2013; Thomas, 2000). On the other hand, the challenges of project-based learning are taking a longer time than traditional instructional methods, increasing teacher workload due to facilitator role in the process, making classroom management difficult since students need to monitor during the process, having lack of knowledge, experience and mastery skills on project-based learning in terms of both students and teachers, and needing financial support for projects (Condliffe et al., 2017; Korkmaz & Kaptan, 2001; Larmer et al., 2015; Moursund, 1999; Tamim & Grant, 2013; Thomas, 2000).

2.3 STEM Education

STEM education is a concept constructed by politicians and policymakers, not as expected by the educators, to reform economic growth and promote workforce and workforce productivity (Bybee, 2013). According to these policymakers, STEM education should be an educational approach that integrates the necessities of schools and mainly economic expectations of the society (Kuenzi, 2008). This integrated approach includes more technical subjects like science, technology, engineering, and mathematics at the core and plays a vital role in the economic development and welfare of the countries which implement it in their education system. If this type of integrated education is implemented, students can have an opportunity to learn and use science, technology, engineering, and mathematics. By doing so, they will be the leaders of change and innovation, which lead to economic growth. So, the roots of STEM education are related to economic concerns rather than educational concerns, as estimated (Bybee, 2013).

The acronym of Science, Technology, Engineering, and Mathematics, namely STEM (Sanders, 2009), was mentioned first in 2001 by Dr. Judith A. Ramaley (Breiner, Harkness, Johnson & Koehler, 2012). After giving voice to STEM more in such academic studies, educators and educational policymakers began to notice the value of STEM education as one of the solutions to the shortage of well-educated students in STEM subjects and high-qualified workers in STEM areas, especially technology (Bybee, 2013).

The definition of STEM education is varied in the literature because of its newness and not having broad and specific literature (Bybee, 2013). Johnson (2012) stated that STEM education is a type of education that integrates science, technology, engineering, and mathematics, and it presents these disciplines to the students transdisciplinary like in real-life. The definition of STEM education by Zollman (2012) supported this transdisciplinary perspective by emphasizing the elimination of the barriers between these subjects in traditional instruction. Çorlu and his colleagues (2014) pointed out the cooperation in the definition of STEM education by underlining the structure of knowledge, skills, and thoughts via cooperation in students and teachers. As a broad definition, STEM education can be considered as an educational approach that contributes to the economic and technological development of countries (NRC, 2011). In addition to these, some researchers asserted that STEM education covers not only science, technology, engineering, and mathematics, but also the arts (Beal, 2013), psychology (American Psychology Association [APA], 2010), entrepreneurship (Camesano et al., 2016), and reading and writing (Israel, Maynard & Williamson, 2013).

2.3.1 STEM Education in Abroad

STEM education is the newest educational policy that attempted to be integrated with education systems in many countries such as the United States, South Korea, United Kingdom, Finland, and China (MoNE, 2016). For example, the United States, where STEM education term was used first, gave weight to questioning strategies in instructions and STEM-related areas to catch rapidly developing scientific and technological workforce in China, since it was seen as a danger to their future goals (MoNE, 2016). They published some reports (such as Tapping America's Potential: The Education for Innovation Initiative and Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future) to point out the concerns about the future and which issues the United States should give priority in education. Another report related to STEM education was Next Generation Science Standards: For States, By States (Next Generation Science Standards [NGSS], 2013), which can be summarized as the integration of science education and engineering in science lessons regarding engineering design process base. The main goal of the STEM education strategy of the United States is to make their students in international exams such as TIMMS and PISA successful and to bring them 21st-century skills (Kuenzi, 2008).

In South Korea, the government and educational policymakers began curricular studies about STEM education to provide a better understanding of science and technology, raising attention to and interest in it and advancing problem-solving skills in 2011 (Park, Kim & Kim, 2012). They adopted STEM disciplines with art, namely STEAM (Science, Technology, Engineering, Arts and Mathematics), to ensure that their students gain creativity skills during their K-12 education (Yakman & Lee, 2012). STEM education is an essential element of reform in Korean schools and possible and stable success in international exams, which are TIMMS and PISA.

EU countries such as Belgium, Denmark, Estonia, and the Netherlands report their concerns about the number of qualified employees in STEM fields since the number of STEM professionals equipped with problem-solving, collaboration, and communications skills are decreasing (EU STEM Coalition, 2016). These concerns lead countries to integrate STEM education into their school curricula to empower STEM-related workforce and 21st-century skills to keep them with the era. For example, the Netherlands developed a STEM education strategy in 2004 to raise well-educated scientists and engineers by supporting science and technology education in schools (Kearney, 2016). Similar to the Netherlands, STEM education is seen as an essential component of the educational strategy developed in Estonia, namely the Estonian Lifelong Learning Strategy. The aim of the strategy is to make STEM-related professions valuable by equipping society with mathematical and scientific skills and technological literacy and increasing the quality of education. (Kearney, 2016).

Like other countries, Finland gives importance to STEM education and has a broader strategic plan for STEM education (Kearney, 2016). According to the plan, the Finnish government supports working groups on STEM education to develop the interest and abilities of students in STEM education and STEM careers. Also, the studies conducted by universities and organizations are supported to develop their own STEM education strategies in order to increase teacher qualifications in STEM education and participate more students in STEM education processes.

2.3.2 STEM Education in Turkey

According to one opinion, STEM education tendency in the Turkish education system was started to be debated due to the students’ poor performances in the international exams (MoNE, 2016), and many stakeholders started to put STEM education into words with the private sector’s guidance (Herdem & Ünal, 2018).

The first integration of STEM education in science and mathematics classes was run in Kayseri, selected as a pilot province on the state level in 2013. The results of these pilot studies revealed that students’ attitudes towards science and mathematics become more positive, and their scores on these courses increase (Akgündüz et al., 2015). Other attempts of STEM education are conducted under the leadership of research centers at universities, non-governmental organizations, science centers, and private schools. For example, some universities such as Middle East Technical University, İstanbul Aydın University, and Bahçeşehir University have research, development, and application centers about STEM education. Almost all private schools have special STEM classes where students learn robotics, coding, programming, and STEM concepts via learning by doing, problem-solving and project-based environment.

Moreover, The Scientific and Technological Research Council of Turkey (TÜBİTAK) organizes contests, projects, and science fairs to develop STEM education. Science centers were established in some cities like Kocaeli and Konya, and out-of-class STEM practices were carried out there. Lastly, many reports with the inclusion of the definition of STEM education, its necessity, the readiness of Turkish schools, teachers, and students to it, and suggestions to integrate it into Turkish school curricula. These reports were prepared by the universities such as İstanbul Aydın University and Bahçeşehir University, organizations like Turkish Industry and Business Association (TÜSİAD) and MoNE. The common point in these reports lays weight on the need to reform the education system to have a qualified workforce in the 21st-century and introduce STEM education as one of the robust methods to respond to this need.

According to these reports, the science curriculum was reorganized, and engineering implementations were integrated into middle school in 2018. The aim of this integration was announced as giving students an engineer’s point of view by combining science concepts and the engineering design process (MoNE, 2018). Although there are some critics to this attempt since engineering was placed in the last chapter and represented as separated from science in that chapter, it can be seen as integrating STEM education in the Turkish science curriculum gradually (Bahar et al., 2018).

The outcomes of the content analysis study about STEM education research papers published in Turkey conducted by Aydın-Günbatar and Tabar (2019) demonstrated that there are research studies made with K-12 students, gifted students, students in special education programs, pre-service teachers, in-service teachers, and academicians, in out-class activities, and to develop STEM education instruments. The findings of the study indicated that participants are students and pre-service teachers in many of the research studies regarding STEM education in Turkey. Specifically, Daşdemir and his colleagues (2018) concluded that the participants of the research studies in Turkey are mostly middle school students. So, there is a need for conducting researches about teachers concerning STEM education. The most examined subjects in STEM education in Turkey are science, engineering, and their relationship. It can be concluded that STEM education studies in Turkey should also be discussed from a mathematical point of view. Views on STEM education and attitudes towards STEM education are the most popular research subjects in Turkey. The researchers concluded that teacher training programs are insufficient in terms of the STEM education approach, implementation of STEM-related activities, and assessment of STEM-related activities in Turkey.

2.4 Mathematical Modelling and Model Eliciting Activities

2.4.1 Models and Modelling Perspective

Models and modelling perspective (MMP), originated from constructivist and sociocultural theories, is an effective educational approach related to mathematics teaching, mathematics learning, and problem-solving in mathematics (Lesh & Doerr, 2003). Models are defined as “conceptual systems (consisting of elements, relations, operations, and rules governing interactions) that are expressed using external notation systems, and that are used to construct, describe, or explain the behaviors of other system(s)” (Lesh & Doerr, 2003, p. 10). In other words, models consist of conceptual systems in the minds as internal components and representations for transferring these conceptual systems to real life as an external component (Lesh & Carmona, 2003). The term “model” is an umbrella term used in various disciplines from agriculture to psychology as well as engineering and economy, and it takes mathematical models in (Lesh & Doerr, 2003). Specifically, mathematical models focus on structural characteristics and functional principles of real-life situations rather than the physical characteristics of the situations (Lehrer & Schauble, 2003). According to Berry and Houston (1995), mathematical models are mathematical representations of relationships between the variables related to real-life situations or problems. Mathematical models are explanations of operations, relations, and representations that enable people to understand real-life situations with the help of mathematical concepts and tools.

2.4.2 Mathematical Modelling

Although the terms model and modelling are closely associated, they are different from each other. Sriraman and Lesh (2006) pointed out this difference by mentioning the relationship between product and process. Mathematical modelling is a process in which models are created, and the (mathematical) models are the products of this process. So, modelling is a process where existing conceptual schemes are developed, and new conceptual schemes are created by exploring, interpreting, and organizing real-life situations and problems. On the other hand, mathematical modelling is a process where effective mathematical models are created and developed by using current conceptual systems and models to generalize them to new contexts (Lesh & Doerr, 2003).

Although mathematical modelling has a crucial role in raising individuals who have analytical thinking skills, are able to solve real-life problems, and equipped with technological competencies according to many studies in the literature (Kaiser & Sriraman, 2006; Lesh & Zawojewski, 2007; MoNE, 2013; Niss, Blum & Galbraith, 2007; Zawojewski, Lesh & English, 2003), there is no common definition of the mathematical modelling process, its purpose, usage, applications in lessons and integration in (mathematics) curriculum (Borromeo-Ferri, 2006; Kaiser & Sriraman, 2006; Niss et al., 2007). According to Berry and Houston (1995), mathematical modelling can be defined simply as a reciprocal interaction between the real world and the mathematical world, as given in Figure 2.3.

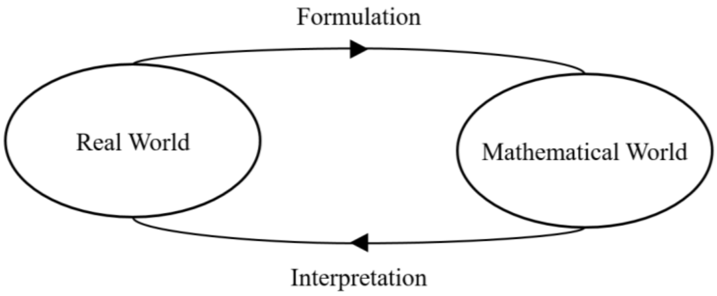

Figure 2.3. A simple representation of mathematical modelling (Berry & Houston, 1995, p. 24)

In the figure, it is stated that formulating answers the purpose of describing and representing a problem in the real world to the mathematical world, and interpreting answers the purpose of providing a solution to the real-world problem by taking its mathematical results into consideration. In other words, the real-life problems are converted to mathematical problems via formulation, and the results of the mathematical results of this formulation are interpreted in terms of their usefulness in the real world.

In the comprehensive report prepared by Consortium for Mathematics and Its Applications (COMAP) and Society for Industrial and Applied Mathematics (SIAM) to guiding teachers in terms of mathematical modelling practices and called Guidelines for Assessment and Instruction in Mathematical Modelling Education (GAIMME), mathematical modelling is defined as “a process that uses mathematics to represent, analyze, make predictions or otherwise provide insight into real-world phenomena” (GAIMME, 2019, p.8). The term “process” is emphasized as an essential characteristic of mathematical modelling. It requires cyclical, hierarchical, or open to revision structures, i.e., the mathematical modelling process is not linear.

The mathematical modelling process reported by GAIMME (2019) is demonstrated in Figure 2.4.

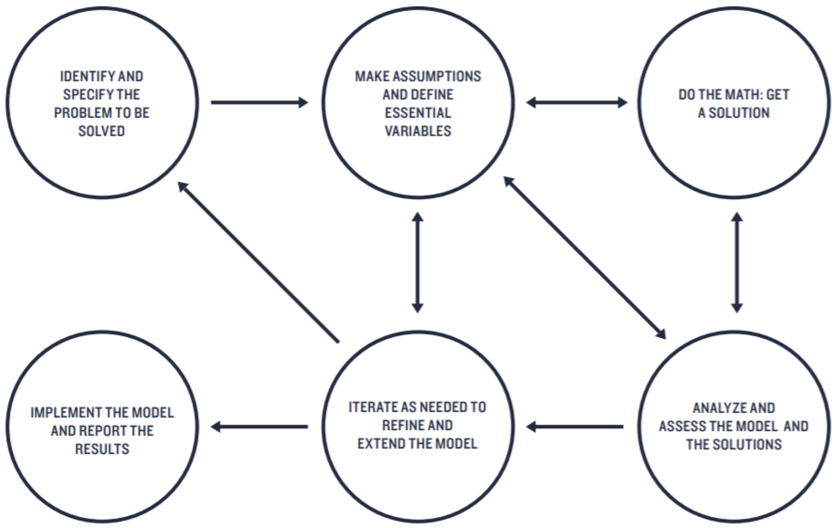

Figure 2.4. The mathematical modelling process (GAIMME, 2019, p. 13)

According to the figure, the cyclical nature of the modelling process is remarked, and unidirectional arrows are used for pointing out the revisions or repeats based on feedback from other components of the process. Although the components of the mathematical modelling process have not been presented as steps or ordered, identifying a real-life problem that wanted to know and understand by the researchers or students is generally the first step of the process. After identifying and specifying the real-world problem, objects and variables that affect the real-world problem and their interrelations are identified. In parallel with the variables, students decide which variables will be kept or ignored in the process, and then the original problem is converted into its idealized version. The idealized version of the real-life problem is explained with mathematical terms via formulation. The result of the mathematical formulation, namely doing math, is a mathematical model. The solutions reached with the help of the mathematical models are analyzed in terms of their practicality, reasonability, and acceptability. If the models are analyzed and decided as practical, reasonable, and acceptable, the process is overviewed and iterated in need of refinement. Lastly, the model is put into practice as an implementation of real-life problem solving, and the process is reported and shared with others.

Similarly, Lesh and Doerr (2003) asserted a four-step cyclic modelling process consisted of description, manipulation, translation, and verification. The following Figure 2.5 is demonstrated their modelling cycle.

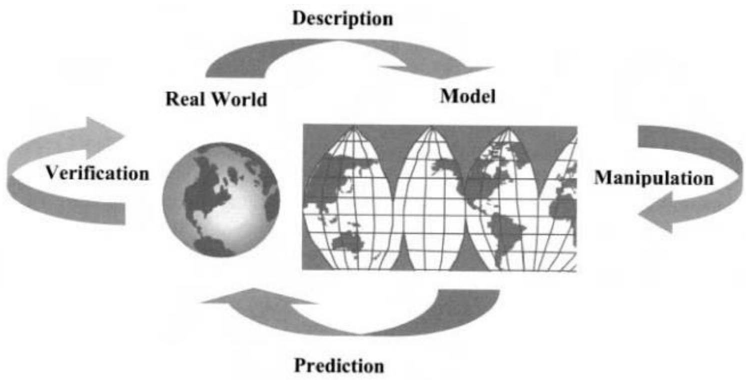

Figure 2.5. Four-steps modelling cycle (Lesh & Doerr, 2003, p. 17)

According to Lesh and Doerr (2003), the modelling cycle begins with a description of the real-life situation by transferring it to the modelling process. The second step is called manipulation, and it includes operations and assumptions related to the model. The third step is called prediction, and it includes estimating the results of the most effective solution of the real-world problem via models and transferring models back to real-life situations. The last step is called verification, and it includes the usefulness and accuracy of the models. Like the before-mentioned modelling process examined by GAIMME (2019), this modelling process can also be repeated if needed, thanks to its iterative nature.

The modelling perspectives in the literature influence the Turkish mathematics curriculum, and the curriculum was revised, including modelling and problem-solving approaches to develop students' mathematical thinking skills and enable them to realize the connection between mathematics and real-life (MoNE, 2013). Mathematical modelling is defined as a dynamic process that makes realizing the relationships between problems in all areas of life, describing them with mathematical terms, classifying them, generalizing them, and drawing conclusions based on them (MoNE, 2013). Besides, the Turkish high school mathematics curriculum is offered a modelling cycle to teachers for use in mathematical modelling activities, and the cycle is given in Figure 2.6.

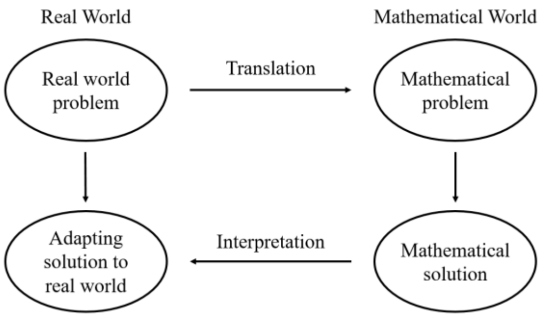

Figure 2.6. Cyclic mathematical modelling process (MoNE, 2013, p. v)

When the cycle is examined, it is seen that the modelling process begins with describing a real-world problem, and then the problem is converted into a mathematical form by representing it mathematically. After the translation of the real-world problem to a mathematical problem, the solution is generated by using mathematical representations, operations, or notations. Finally, the models obtained from the mathematical solution are interpreted for their usability, considering real-world situations.

To sum up, mathematical modelling has different definitions in the literature, and the structure of the mathematical modelling process similar in these studies in terms of its cyclic and iterative nature. It can be concluded that modelling processes are mostly related to detecting and describing a real-world problem and trying to find a solution to it by using mathematization as a strategy for generating models. Then the process continues with testing these models whether they meet the need for real-world problem solutions or not by indicating their usability. If the models do not work properly for understanding and solving the problem, they can be revised, or researchers can develop new models by revisiting the modelling process.

2.4.3 Model Eliciting Activities

Lesh and his colleagues (2003) identified three stages of model development sequences within the scope of MMP in order to engage students in modelling processes. These stages are model-eliciting activity, model-exploration activity, and model-adaptation activity, as shown in Figure 2.7. According to them, these stages should be met for several purposes, such as enabling teachers to understand students' mathematical thinking, leading them to investigate the interaction between students and also them, and emphasizing the importance of real-world problems' solutions by using mathematical language.

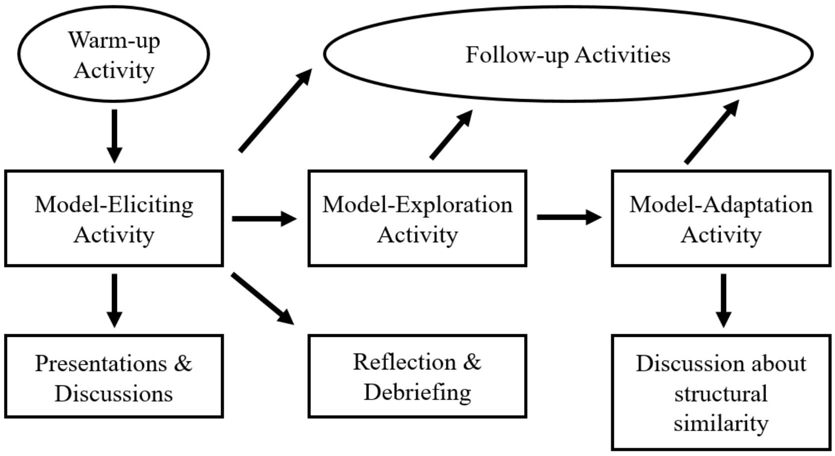

Figure 2.7. A scheme for model development sequences (Lesh, Cramer, Doerr, Post, & Zawojewski, 2003, p. 45)

According to the model development sequence scheme, the first stage of the modelling is model-eliciting activities. The model-eliciting activities can be defined as mathematical modelling activities that require interpreting real-life problems by using mathematical language and creating a definition, operation, or strategy in order to adapt or expand the solution to other real-life problems (Lesh & Zawojewski, 2007). In model-eliciting activities, students work collaboratively and construct their mathematical models to demonstrate their mathematical thinking. By doing so, teachers have an idea of their weaknesses and strengths in terms of mathematical conceptions and shape their instruction according to them for the next stage. In model-exploration activities, the models created by students are thought and interpreted by other groups to understand the model and develop it if needed. In model-adaptation activities, students are asked to adapt their models or create new models to be able to transfer their models to new real-life situations. Besides, the modelling sequence can be adapted by modifying, adding, skipping, or changing the order of stages according to their students' level and needs by teachers (Lesh et al., 2000).

MEAs include non-traditional, open-ended, and complex problems in real-world contexts and require that students work in teams to build their conceptual understanding in mathematics during the modelling process (Lesh & Doerr, 2003). Students are asked to explore real-life problems with their mathematical knowledge and develop models to solve the problems in relatively short class hours (Erbaş et al., 2014). MEAs have four main components: (i) reading passage, (ii) readiness question, (iii) data, and (iv) problem-solving task (Chamberlin & Moon, 2005). According to Lesh and Doerr (2003), these components are newspaper articles, readiness questions, problem statements, and sharing solutions. The components asserted by the different researchers have similar characteristics. The first two components are used for introducing the real-life problem and to students in order to make them familiar with the context of the problem. Teachers give newspaper articles, or brochures and students are asked to discuss and interpret the given materials. These two components have the purpose of gaining students' attention to the lessons, and they are like warm-up activities at the beginning of the lesson. The third component is the central part of MEAs since it includes the implementation of the activity and creating models as a solution for real-life problems. The last component is related to the presentation of the models and the modelling process to other groups, and students discuss their models to develop and revise them.

MEAs have six design principles for creating productive MEAs offered by Lesh et al. (2000). These design principles are (i) reality principle (personal meaningfulness principle), (ii) model construction principle, (iii) self-evaluation principle, (iv) model externalization (model documentation principle), (vi) simple prototype principle, and (v) model generalizability principle. Briefly, MEAs should be based on real-life problems that can be encountered by the students as their contexts and should be consistent with students' experiences, backgrounds, and interests to be able to solve the problems to ensure reality principle. MEAs should lead students to develop a mathematical model at the end of the mathematical modelling process. In other words, Problems given in MEAs should necessitate the need for a model to be developed, modified, and revised to ensure model construction principle. MEAs should enable students to evaluate the appropriateness and usefulness of their models and checking whether their models need to be modified by deciding on their own to ensure the self-evaluation principle. MEAs should be conducted in an environment where students can demonstrate their mathematical thinking during the process by documenting their solutions with reasons in written form to ensure the model documentation principle. MEAs should enable students to develop understandable and useful models with a high explanatory power that allow others to interpret other real-life situations to ensure a simple prototype principle. Lastly, MEAs should lead students to develop models that can represent other real-life situations thanks to the models' reusable and modifiable nature to ensure model generalizability principle. Developing MEAs to include these principles helps teachers to enhance students' mathematical reasoning by meeting the standards of the mathematical modelling process and encouraging mathematical modelling behaviors (Lesh et al., 2000).

Implementing MEAs can be a difficult practice for mathematics teachers when compared to their regular classes. Similar to offering frameworks for developing effective MEAs, there are studies about the role of teachers during the mathematical modelling process to enhance the quality of implementation (GAIMME, 2019). Carlson and her colleagues (2016) developed a framework for implementing and teaching modelling effectively with students. The following Figure 2.8 is demonstrated the role of the teacher during the modelling process.

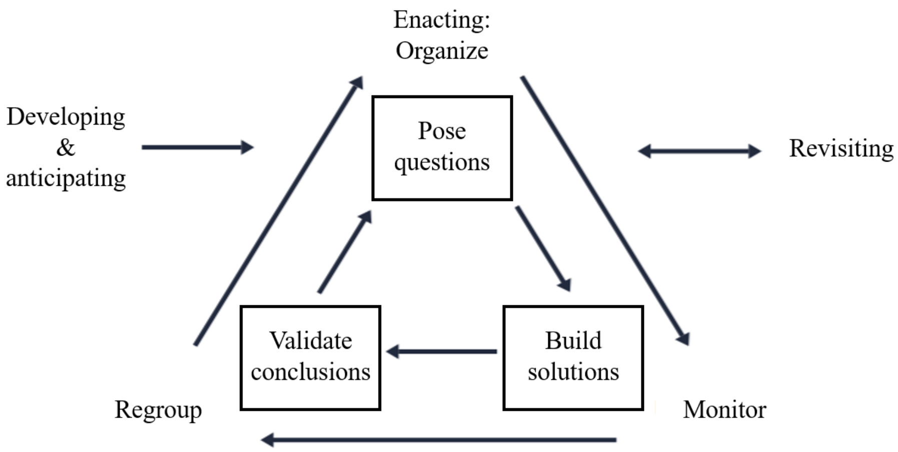

Figure 2.8. Teachers' roles in facilitating modelling (Carlson et al., 2016)

In the figure, the inner cyclic process represents the simplified version of the modelling process that students involved in mathematics lessons. According to this version, the mathematical modelling process includes three steps: posing questions, building solutions, and validating conclusions. The outer cyclic process represents teacher actions, which are organizing, monitoring, and regrouping. The other components represent teaching actions, which are developing and anticipating, enacting, and revisiting. The implementation of mathematical modelling should begin with teachers' planning by developing a real-life problem and anticipating the students' possible reactions and solutions. After developing and anticipating step, teachers should implement their activities by organizing their instruction in terms of presentation of a real-life problem, introducing the context of it, and students' group working. While students work on mathematical modelling activities, teachers should monitor them by observing strategies, mathematical thinking, strengths, and weaknesses during the implementation. Teachers can regroup students due to their observations. They should use a regrouping strategy to allow students to share their ideas and solutions with others, give different feedback from others, overcome difficulties encountered in the modelling process, and clarify the given tasks. By doing so, teachers can create a learning environment where students have an opportunity to enhance their mathematical reasoning and develop different mathematical models. Teachers should revisit the mathematical modelling process to evaluate their instruction, revise the activity by taking students' level and needs into account and extend the mathematical modelling activity.

2.5 Review of the Related Literature

In this part, studies related to teachers' experiences and implementations related to STEM and mathematical modelling activities and the effects of these activities on students will be presented as a review of the literature in the light of the purpose of the current study.

Herro and Quigley (2017) conducted a multi-year study to examine views, perceptions, and classroom practices of middle school mathematics teachers in the United States. 21 teachers participated in a professional development program regarding STEM education. The data of this case study was obtained from surveys, observation, reflections, and focus group interviews. Teachers used digital tools to share their artifacts during the program and communicate with each other while exploring their STEM education teaching practices. The results showed that a professional development program is effective in enhancing teachers' understanding of STEM education. For instance, some of the teachers realized the importance of integrating art into their lessons as an aspect of STEM education. Technology integrated programs had a positive effect on changing teachers' practices, such as collaborating with others and enhancing the learning process with technological tools.

Park and his colleagues (2016) conducted research in South Korea with the purpose of examining the practices of 705 STEAM teachers. According to the results of surveys, teachers had positive perceptions of STEAM education in terms of promoting student learning, 21st-century skills, and character-building, such as having a tendency to collaborate. Besides positive views on STEAM education, teachers pointed out some challenges in implementing their STEAM education activities. Finding time for planning and implementing the activities and increased workload of teachers were stated as difficulties encountered. School managements' lack of moral, material and financial support was another challenge in implementing STEAM activities.

Similar to the studies mentioned above, Wang, Moore, Roehrig and Park (2011) carried out research to explore the effect of a year-long professional development program related to STEM education with three middle school teachers in the United States. The results of this qualitative case study indicated that teachers need to know how they integrate STEM education into their lessons. Also, they experienced that effective STEM integration is strongly related to the inclusion of the problem-solving process in lessons. Lastly, they had difficulty in integrating technology into their lessons.

Eroğlu and Bektaş (2016) carried out a phenomenological study to investigate the views of teachers who have knowledge about STEM education and participated in STEM education training. The data were collected using semi-structured interviews with five science teachers in a city in central Anatolia. Teachers stated that they used STEM activities mostly as out-of-class contexts. According to teachers, using STEM activities in science lessons had several advantages, such as teaching concepts more effectively, motivating them, and better engagement of students in lessons. The advantages related to students were pointed out as motivating them for learning, gaining attraction and interest, developing 21st-century skills, promoting self-confidence, increasing academic achievement, and fostering their psychomotor skills. On the other hand, the results of the study demonstrated that STEM activities have limitations and difficulties such as requiring more time, lack of teacher knowledge about integration, material, and financial support according to teachers' perceptions. Lastly, teachers recommended making planning and preparation before the implementation well by considering students' backgrounds and attending professional development seminars to have knowledge and experience about STEM education to teachers who implement STEM activities in their lessons for the first time.

Özbilen (2018) conducted a similar study to identify teachers' STEM education awareness and examine their views on STEM education by using structured interviews with science, mathematics, and technology-design teachers. She concluded that science teachers are more knowledgeable about STEM education and use it more in their lessons compared to mathematics and technology-design teachers. Teachers thought that they need in-service training to be able to integrate STEM disciplines, especially engineering, into their disciplines. Teachers overcame the barrier related to their lack of knowledge with their own effort. Although they were disposed to implement STEM activities, they had some drawbacks related to lack of collaboration with colleagues, theoretical and practical knowledge about STEM education, and material. Moreover, teachers asserted STEM activities as enabling them to attract students' attention and demonstrate real-life implementations of their subjects.

Kurtuluş, Akçay and Karahan (2017) carried out qualitative research with high school mathematics teachers to examine their views on the effectiveness of STEM education in a city in central Anatolia. Researchers organized a workshop for teachers before the data collection to inform them on the theoretical background of STEM education and lead them to learn characteristics of STEM education by conducting an activity. The findings of the study showed that teachers perceive STEM education as an instructional method that requires problem-solving and creativity, allows students to realize the practical side of their knowledge via STEM activities, and fosters analytical thinking and brainstorming. According to teachers, STEM activities affect students' problem-solving, higher-order thinking, critical thinking, creativity, and decision-making skills, leading them to connect real-life and the concepts learned in an interdisciplinary way and gaining positive attitudes towards mathematics. On the other hand, they perceived having a lack of material, having limited time for covering curriculum, instructing in crowded classes, monitoring students during the activities, and preparing students for national exams as potential barriers they may encounter. To conclude, although STEM integration into lessons is favored by teachers, they have difficulties in the integration process due to their lack of knowledge and experience, limited time, increased workload, and lack of support. However, the positive effects of STEM integration on students, such as maximizing their learning and developing skills, lead them to implement STEM activities.

Akgün and his colleagues (2013) carried out a study to investigate the views of middle school mathematics teachers on mathematical modelling. The researchers conducted their phenomenological study with the participation of 11 middle school mathematics teachers in a city in eastern Turkey. The data obtained from semi-structured interviews with all participants and in-class observations of four of the participants in their 6th and 8th-grade classes. The research found that teachers have inadequate knowledge of the mathematical modelling process since their activities do not meet the characteristics of modelling activities, such as lack of real-life connections in their problem contexts. Another finding of the study is related to time, and teachers complain about their lack of time for implementing activities since they require more time compared to regular activities, and the mathematics curriculum has intensive objectives. Teachers also indicated their need for technological tools to implement mathematical modelling activities and pre-service teacher training programs to know such approaches before entering the teaching profession. Because of these, they used mathematical modelling activities in their lessons rarely.

Unlike the study of Akgün et al. (2013), Tekin-Dede and Bukova-Güzel (2013) conducted a study with high school teachers in a city west of Turkey who have no experience in implementing mathematical modelling activities in their lessons. The aim of the study was to investigate high school mathematics teachers' views regarding MEAs in the workshop process in which teachers were enabled to know, design, and implement MEAs. Teachers were interviewed before and after the workshops to learn their perceptions about MEAs in terms of definitions, advantages, and disadvantages. Although teachers did not implement MEAs in their classes by stating that they did not know what MEAs are, they defined MEAs in parallel with literature by mentioning problem-solving, developing a model, and a process-based approach. Also, they emphasized their motivation to learn more about and implement

MEAs after the workshop. Teachers concluded that implementing MEAs has advantages and disadvantages. They mentioned limited time for preparing and implementing MEAs due to covering intensive mathematics curriculum as a disadvantage. On the other hand, they thought that MEAs provide integration of mathematical concepts and also mathematics and other disciplines, increasing student learning by motivating them, getting their attention, and connecting real-life and mathematics.

Yu and Chang (2011) carried out a study with sixteen high school mathematics teachers in Taiwan to examine their perceptions and obstacles of MEAs after designing and implementing MEAs in a graduate course. Teachers' reflection journals, researchers' observation journals, questionnaires, interviews, and videos were used to collect data about teachers' experiences during the course. At the end of the course, teachers had knowledge and experience about MEAs and considered that MEAs should be used in mathematics lessons since they support students' problem-solving skills. Also, they considered MEAs as an essential component of mathematics lessons since they allow them to use open-ended and real-life problems to enhance student learning. Due to these positive perceptions of MEAs, it was reported that teachers had positive attitudes and motivation to implement MEAs in their mathematics lessons. However, they mentioned obstacles encountered in the implementation of MEAs and pointed out that the effective implementation of MEAs is related to overcoming these obstacles. The obstacles emphasized by the teachers were about materials, mathematics curriculum, exams, and familiarity with MEAs. Teachers were concerned about lack of materials in schools, lack of integration and connection of MEAs and mathematics curriculum, national exams as a reason of resisting to implement and their lack of knowledge about how they implement MEAs in mathematics lessons.

Similar to the above-mentioned studies, Frejd (2012) conducted a research study to investigate eighteen high school mathematics teachers' conceptions, views, and experiences of mathematical modelling activities in Sweden. The data obtained from questionnaires indicated that teachers have limited experiences of mathematical modelling in their lessons and believed that modelling could be more suitable for physics and chemistry classroom settings. Because of these reasons, they did not prefer to integrate mathematical modelling activities into their mathematics lessons. Besides, developing students thinking skills and showing them how mathematics is used in real-life lead them to implement mathematical modelling activities more.

Deniz and Akgün (2017) carried out a phenomenological study with thirteen high school mathematics teachers to determine their views on mathematical modelling and classroom practices in a city in eastern Turkey. They collected data with semi-structured interviews. Researchers used pre-interviews and post-interviews since they conducted a workshop for teachers to inform them about MEAs. After the workshop, participant teachers designed forty-nine MEAs and implemented them during the school year. The results of the interviews revealed that implementing MEAs in lessons promotes teachers' perception of making a relationship between mathematics and real-life since they acquired knowledge, skills, and experiences related to MEAs. Teachers explained the purpose of using MEAs in instructions as enhancing concrete learning, emphasizing the connection between real-life and mathematics, motivating students, engaging them in lessons, increasing academic achievement, and getting students' attention. In pre-interviews, teachers asserted possible difficulties encountered in the implementation of MEAs as students' lack of familiarity with MEAs, being different from the question types in national exams, teachers' lack of knowledge about integrating mathematics into real-life. In post-interviews, they pointed out difficulties encountered in the implementation of MEAs as being time-consuming, students' lack of familiarity with MEAs, requiring group work, students' low level of readiness to MEAs, and being different from the question types in national exams. The difficulties expressed in the pre-interviews were related to teachers, students, and national exams, while in the post-interviews were related mostly to students due to practicing MEAs in classrooms. Another remarkable change in teachers' views due to practicing MEAs was related to the curriculum. Although most of the teachers indicated that the high school mathematics curriculum includes mathematical modelling sufficiently in pre-interviews, they decided that the curriculum is insufficient and ineffective in terms of mathematical modelling in the post-interviews. In addition, teachers asked to state the difficulties encountered in planning MEAs. These difficulties were reported as constructing and presenting the relationship between mathematics and real-life, having a lack of knowledge and experiences about MEAs, and simplifying and adapting MEAs according to students' levels. Lastly, teachers thought that there is a need for integrating mathematical modelling into teacher education programs, designing mathematical modelling lessons in schools, and leading teachers to collaborate to ensure interdisciplinarity.

In conclusion, mathematics teachers have limited knowledge and experience in mathematical modelling activities due to barriers encountered during the modelling process, such as insufficient knowledge, lack of time, exams, or lack of materials. However, they tend to give priority to implement mathematical modelling activities since they motivate their students, enhance their mathematical knowledge, and enable them to make a connection between real-life and mathematics.

CHAPTER 3

METHODOLOGY

In this chapter, the methodology of the study will be presented in detail. The design of the study, participants of the study, data collection tool, data collection process, and data analysis process will be explained. Then, the trustworthiness, ethical considerations, assumptions, and limitations of the study will be addressed.

3.1 Design of the Study

The main goal of the current study was to investigate middle school mathematics teachers' views and experiences regarding innovative mathematics learning activities by producing a detailed description of features of the implemented activities, emotional engagements of the teachers during the activities, perceived effects of these activities on students, enablers, and barriers for the implementation of the activities, and suggestions of the teachers about these activities based on their views and lived experiences. In order to reach this aim, a qualitative research design was used.

According to Creswell (2014), qualitative research designs should be used when researchers intended to investigate a problem or an issue in order to identify variables that can be measured after the identification and clarification processes. Qualitative research designs represent the perceptions and experiences of individuals in their natural settings with a holistic perspective by using qualitative data collection methods such as content analysis, observation, and interview (Merriam & Tisdell, 2016). In other words, social issues can be understood with the help of qualitative research designs.

In qualitative research designs, what will be observed, what kind of questions will be asked, and how these are related to the research are depended on the theoretical framework and related discipline (Merriam & Tisdell, 2016). Besides, researchers try to explore and understand the experiences, reactions, perceptions, and interpretations of individuals deeply in qualitative research designs (Fraenkel, Wallen & Hyun, 2012). Qualitative research designs provide detailed information about a small number-sized group of individuals to researchers. However, they have limitations in generalizing the research results since they are only suitable for using the phenomena in this small-sized group of individuals (Lodico, Spaulding & Voegtle, 2010).

In the current study, the aim is to investigate middle school mathematics teachers' views and experiences about the implementation of innovative mathematics learning activities. Accordingly, the design of the study was phenomenological research, one of the qualitative research designs (Patton, 2015). Phenomenological research can be used to investigate a phenomenon that we know little about. In this type of research design, information is collected from knowledgeable and experienced participants who are asked to describe the phenomenon based on their experiences. The phenomenological research puts forth people's lived experiences and represents the broad descriptions of the common points in them (Moustakas, 1994). This type of study is the best research type for obtaining people's views, thoughts, and experiences about a concept or an approach (Mills & Gay, 2016).

In brief, phenomenology refers to studying people's views and experiences (Creswell, 2007). This also frames how middle school mathematics teachers perceive innovative mathematics education and interpret their experiences about implementations of the related activities through semi-structured interviews. Therefore, it can be said that the particular phenomena of the current study is the experiences of middle school mathematics teachers' who have implemented innovative mathematics learning activities in their instruction. Also, it is aimed to gain insight into their perceptions, emotional engagements, enablers, barriers, and suggestions related to innovative mathematics learning activities. Based on the nature of phenomenological research, it was assumed that the participant middle school mathematics teachers had similar views on innovative mathematics learning activities and experiences on their planning, implementation, and evaluation processes.

3.2 Participants of the Study

The study's target population was all middle school mathematics teachers who have theoretical knowledge about innovative mathematics education and implement innovative mathematics learning activities in their school contexts at middle school grade levels in Turkey. However, since it was hard to reach all of them and conflicted with the nature of qualitative research designs, the purposive sampling method was used in the current study. According to Lodico et al. (2010), when researchers have former knowledge and judgments about the population, they use the purposive sampling method by choosing a sample from this population for a particular purpose of the study.

Snowball sampling was used as a type of purposive sampling method. In snowball sampling, a group of people is selected based on specific characteristics and experiences. Then others are selected according to these participants' recommendations since they are known as knowledgeable and experienced in terms of the research subject (Fraenkel et al., 2012). So, the participants help the researcher to find potential participants of the study by nominating others with similar characteristics and experiences.

In qualitative research, there is not a precise recommended number of participants due to its nature. There are different views about the proper sample size (Lodico et al., 2010). Since there is no absolute rule regarding the number of participants in qualitative research designs (Patton, 2015), Seidman (2006) asserted to carry research on until taking similar responses from the participants and estimating the responses of the participants. So, getting similar responses and being able to estimate participants' responses were criteria of the sample size of the current study.

The participant teachers were chosen according to references and recommendations of already known and firstly-chosen teachers by the researcher. One of these first teachers selected at the recommendation of mathematics education domain expert, and the other teacher selected according to her research and effort on implementing non-traditional methods in lessons. The teaching practices of the first two teachers were known by the researcher due to their acquaintanceship in undergraduate education and teaching intern. Then, the researcher made a telephone conversation with recommended participants to get information about their innovative mathematics learning activities and to inform them about the study before the data collection process. It was preferred to access them conveniently in terms of time, and they participated in the study voluntarily. In addition, almost all of the participants were asked to nominate other teachers who implemented similar activities to reach potential participants. Interviewing with teachers conducted until being able to estimate responses of them. Since teachers and their recommended colleagues have similar characteristics, teaching styles, and experiences, it was started to take similar responses after approximately ten interviews. In brief, the current study was conducted with middle school mathematics teachers selected based on their specific experiences on innovative mathematics learning activities, and it was carried out until being able to understand their views and experiences deeply and estimate their reactions and responses.

The participants of the study were thirteen middle school mathematics teachers who have both theoretical and practical knowledge about innovative mathematics education. Three of them were public school teachers in Ankara, Gaziantep, and Sakarya, and ten of them were private school teachers in Ankara, Düzce, and İstanbul. All of the participant teachers -except one of them- were female. All of them had teaching experience at all grade levels of middle school, including their internships. Demographic information about participant teachers is presented in Table 3.1.

Table 3.1 Demographic Information about Participants

Pseudonym of the Participant	Undergraduate Education	Years of Experience	School of Employment	Graduate Education
P1	Mathematics Education	4 years	Public school	M.S. in Educational Measurement and Evaluation (ongoing)
P2	Mathematics Education	3 years	Private school	M.S. in Mathematics Education (ongoing)
P3	Mathematics Education	2 years	Private school	-
P4	Mathematics Education	6 years	Public school	M.S. in Mathematics Education
P5	Mathematics Education	7 years	Public school	M.S. in Mathematics Education (ongoing)
P6	Mathematics Education	3 years	Private school	-
P7	Mathematics	8 years	Private school	M.S. in Mathematics
P8	Mathematics Education	5 years	Private school	-
P9	Mathematics	10 years	Private school	M.S. in Curriculum and Instruction
P10	Mathematics Education	2 years	Private school	M.S. in Mathematics Education (ongoing)
P11	Mathematics	20 years	Private school	M.S. in Educational Administration and Planning
P12	Mathematics Education	10 years	Public school	Ph.D. in Mathematics Education (ongoing)
P13	Mathematics	9 years	Private school	M.S. in Curriculum and Instruction

3.3 Data Collection Tool

In phenomenological studies, the data are usually obtained from interviews, observations, and documents (Merriam & Tisdell, 2016). Interviews (unstructured, semi-structured and structured) can be considered as “conversation with a purpose which is to gather information” (Lune & Berg, 2017, p. 65) and are commonly used by the qualitative researchers while collecting data (Yıldırım & Şimşek, 2018). In the current study, the data were gathered via semi-structured and face-to-face or online interviews. The reason behind the selection of the interview as a data collection tool was getting to know in-depth and detailed information about the participants’ views and experiences regarding innovative mathematics education, enablers and barriers of the implementation process of their innovative mathematics learning activities, and their suggestions about constituting innovative mathematics education in Turkey.

The researcher developed the semi-structured interview protocol. The interview protocol included 19 questions and follow-up questions for some of them (Appendix A). It was prepared by considering the related literature and taking expert opinion while developing and putting it into final form. Besides, follow-up questions were formed, keeping to prevent generalized opinions of participants in mind. To make interviews more clear and get specific views and experiences, follow-up questions such as “Please give an example.”, “What are the characteristics of it?” and “How was your experience about it?” were designed (van Manen, 1990).

The interview protocol questions aimed to find out views and implementations of middle school mathematics teachers about innovative mathematics education, enablers and barriers they experienced while implementing innovative mathematics learning activities, and their suggestions to overcome these barriers and develop innovation in mathematics education in Turkey. The interview started with the questions about participants’ demographic information such as their educational background, the number of years in the profession, and grade levels that they have the experience. The questions were categorized under the following three headings:

General, Implementation, and Evaluation/Interpretation. All of these categories were associated with the participant teachers' innovative mathematics education experiences. The interview protocol of the study will be given in Appendix A.

3.4 Data Collection Process

The data collection process began after getting necessary permission from the Research Center for Applied Ethics of Middle East Technical University (METU). The selected sampling method described in detail above showed the data gathered through personal access to teachers, namely invitation, not in their schools, institutions, or organizations. Therefore, although the participants were in-service mathematics teachers working in private or public schools affiliated with the MoNE, the researcher did not interview them there because of the individuality of the access and the interviews. So, the individual consent forms were prepared for the participants.

After finalizing the interview questions with the help of the expert revisions and having ethical permission, data collection started with the pilot interviews. The pilot study was conducted with two in-service middle school teachers who worked in private schools in Ankara and Mersin. The pilot interviews helped to test, clarify, and enhance the interview questions by revising them in aspects such as content, order, or wording.

The current study conducted on a volunteer basis, and the participants were notified about it. Before the interviews, the researcher ensured that the participants know the aim of the research, the interview process, and the data analysis process. This information was also given to them via an informed consent form in written form, and they signed it to become a participant of the research. The interviews were face-to-face or online, depending on the convenience of the process, and they were audio-recorded after the participant teachers' signed consent. No access of others to their recordings -except the researcher- and the use of their interviews only for scientific purposes emphasized before starting the interview by the researcher. Also, the participants were informed about withdrawal right if they wanted to do it during any time of the interviews.

In addition, the duration of interviews depended on the participant teachers' available time, and places of interviews were chosen as appropriate as possible. The researcher chose environments where participants feel comfortable and safe and away from distractions like noise or dimmed/bright light in face-to-face and online interviews. The average duration of the interviews was 90 minutes, and it was in accordance with the teachers' enthusiasm and desire to share their experiences. Lastly, the data were collected in the 2018-2019 spring semester.

3.5 Data Analysis

Lodico and her colleagues (2010) recommend six stages to analyze the data in qualitative research designs. The first stage is about preparing and organizing the collected data for analysis, then comes examining and exploring the data, arranging data according to their similarity and dividing them into categories called codes, making intense descriptions and inferences of the data, constructing common theme, and lastly reporting and interpreting data via codes and themes. The researcher followed these six steps in data analysis. The qualitative data obtained from the interviews were analyzed utilizing the content analysis method.

The data collected in the interviews transcribed to work with data efficiently. After the redaction of audio-taped interviews as transcriptions, they were studied, and similar views, experiences, enablers, barriers, and suggestions about innovative mathematics learning activities under codes and themes formed by the researcher. During the data analysis process, there was a second coder. The second coder was a graduate student in mathematics education at METU and had knowledge and experience in qualitative research designs. The researcher and the second coder followed the data analysis stages separately and then compared codes, themes, and categories by coming together for consistency. Finally, representations such as tables and texts were used to effectively demonstrate the data analysis findings to the readers.

3.6 The Trustworthiness of the Study

Validity and reliability are the two primary criteria for judging the quality of research studies. These two essential criteria have an effect on data collection, data analysis, data interpretation, and reporting findings processes (Merriam & Tisdell, 2016). In addition, these two terms are used mainly in quantitative research designs as internal validity, external validity, and reliability. Since quantitative and qualitative research designs are different from each other as a matter of their nature, the trustworthiness of qualitative research designs cannot be explained entirely by the terms validity and reliability. According to Lincoln and Guba (1985), credibility, transferability, dependability, and confirmability are four criteria to ensure the trustworthiness of qualitative research designs. These four criteria substitute for internal validity, external validity, reliability, and objectivity, respectively.

The first criterion of ensuring trustworthiness in qualitative research designs is credibility referring to internal validity. Internal validity is concerned with whether the findings of the research studies match reality or not (Merriam & Tisdell, 2016). Merriam and Tisdell (2016) address five strategies for increasing the credibility of a qualitative research study: (i) triangulation, (ii) member check (respondent validation), (iii) adequate engagement in data collection, (iv) researcher's position (reflexivity), and (v) peer review (peer examination). In the current study, member check, adequate engagement in data collection, researcher position, and peer review strategies were utilized to increase the credibility of the study.

For providing member check strategy, the transcribed texts of the interviews and preliminary analysis of these texts were shared with some of the participants to take their opinions and feedback about the harmony between the transcripts and their words, and the researcher’s interpretations about their words. The aim of this strategy was to get approval from the participants about what they refer in the interview and what the researcher understands from their interviews. For providing an adequate engagement strategy, the researcher interviewed middle school mathematics teachers until the teachers mentioned similar things, and the researcher realized that the new interviewee would not mention anything different, namely saturation of the data and findings (Merriam & Tisdell, 2016). For providing reflexivity strategy, the researcher asserted her role in the research process by mentioning her biases, dispositions, and assumptions, since it is emphasized that detecting and reporting these biases, dispositions, and assumptions are more valuable than to eliminate them (Creswell, 2007). The role of the researcher in the current study was creating a data collection tool, interviewing teachers by using it, analyzing the views and experiences of the teachers, and reporting the findings of the data analysis. In addition, the researcher participated in a seminar about qualitative research designs and conducted a pilot study before starting the current study for reducing her biases as much as possible. For providing peer review strategy, feedback, comments, and suggestions about the data collection tool, interviews, and findings received from the thesis supervisor and the thesis committee members were taken into consideration, and these materials were presented as their revised final version.

The second criterion of ensuring trustworthiness in qualitative research designs is transferability, referring to external validity. According to Merriam and Tisdell (2016), external validity is “concerned with the extent to which the findings of one study can be applied to other situations” (p. 253). So, it is related to the generalizability of the findings of a research study to similar settings (Yıldırım & Şimşek, 2018). Rich and thick description is presented as a strategy for increasing the transferability of the qualitative research studies by Merriam and Tisdell (2016). Therefore, the participants, data collection process, data analysis process, and the findings of the current study were presented in detail for supporting the readers’ understanding and interpretation in terms of transferring the findings of the study to similar contexts.

The third criterion of ensuring trustworthiness in qualitative research designs is dependability, referring to consistency or reliability. Reliability deals with whether the findings of research studies are consistent with data obtained when the study is repeated (Merriam & Tisdell, 2016). Merriam and Tisdell (2016) address four strategies for increasing the dependability of the qualitative research studies: (i) triangulation, (ii) peer review (peer examination), (iii) investigator's position (researcher's position), and (iv) audit trail. As mentioned before, peer review and the researcher's position strategies were used to ensuring the credibility and dependability of the current study. In addition, data collection, interpretation, and analysis processes were explained in detail for ensuring the use of the audit trail strategy.

The last criterion of ensuring trustworthiness in qualitative research designs is confirmability, referring to objectivity. Objectivity is about avoiding and eliminating the researcher's subjective views and decisions (Fraenkel et al., 2012). The detailed description of the whole research process and the role of the researcher in the process were addressed foregoing in order to ensure the objectivity of the current study.

3.7 Ethical Considerations of the Study

To provide confidentiality, the participants' names were kept hidden, and pseudonyms such as P1, P2 were used. As it was mentioned before, the data obtained from the participants were and will be kept confidential and not shared with anyone, except for scientific purposes.

It was avoided to harm participants physically or psychologically. Participants were informed about the study by the researcher before the interviews. It was stated that the data obtained from them would not be used for grading or evaluating them, their implementations or teaching style. Teachers were not forced to participate in the study. The study was conducted based on the voluntariness of them. Lastly, permission from the Research Center for Applied Ethics of METU was received to prevent any unethical issues in the study (Appendix C).

3.8 Assumptions of the Study

The current research was conducted based on some assumptions. Firstly, it was assumed that the interview questions were clear, appropriate, and sufficient to reach the aim of the study.

Secondly, it was assumed that the participant teachers' innovative mathematics learning activities match with the definition of the term researcher uses. Thirdly, it was assumed that they reflected their knowledge and experiences about their innovative mathematics learning activities honestly. Also, it was assumed that they responded to the questions asked in the interviews accurately. Lastly, it was assumed that the researcher interviewed the teachers without any prejudgments about their knowledge and experiences during the data collection and implementation processes.

3.9 Limitations of the Study

The limitations of the current study that should be recognized are generalizability and researcher bias. First of all, the purposive sampling method was used to select participants, and they were limited to thirteen middle school mathematics teachers who were working at different public and private schools in five different cities in Turkey (Ankara, Düzce, Gaziantep, İstanbul, Sakarya) in the academic year of 2018-2019. Therefore, the findings of the research cannot be generalized to a larger group of middle school mathematics teachers because of the limited number of participant teachers. Another limitation of the study was related to researcher bias, like almost all other qualitative research designs naturally. According to Merriam and Tisdell (2016), one of the most critical instruments in qualitative research designs is the researcher, especially when collecting and analyzing the data. The researcher's position to eliminate bias was reported in detail previously.

CHAPTER 4

FINDINGS

In this chapter, the findings based on the data analysis will be presented. The primary purpose of the data analysis was to investigate the views of middle school mathematics teachers about innovative mathematics learning activities. The findings of the study will be reported under seven main sections: (i) teachers' perceptions of innovative mathematics education, (ii) attributes of their innovative mathematics learning activities, (iii) perceived emotions of teachers during innovative mathematics learning activities, (iv) perceived effects of innovative mathematics learning activities on students, (v) enablers of providing innovative mathematics learning activities**,** (vi) barriers in the process of innovative mathematics learning activities, and (vii) suggestions about innovative mathematics learning activities.

4.1 Teachers' Perceptions Regarding Innovative Mathematics Education

The participating teachers were asked what they understood of the term "innovative mathematics education" in the interviews. Their descriptions were mostly based on non-traditional educational approaches (Table 4.1). The table illustrates the participant teachers' definitions of innovative mathematics education, grouped under main categories in the first column, sample coded responses representing these categories in the second column, and frequency of these categories in the last column.

Table 4.1 Overall Information about the Teachers' Perceptions of Innovative Mathematics Education

Main category	Example quote(s)	Frequency
Student-centered	"When you say innovative mathematics education, exactly putting students in the center comes to my mind-putting them in the center, starting to plan the lesson with their prior knowledge, constructing their new concepts out of their prior knowledge. I mean setting traditional methods aside and creating an environment where students can both have fun and learn. So, these kinds of things are coming to my mind." (P5) "… So, innovative education is shaping your lessons according to students' need, interests, and knowledge." (P9)	10
Connecting real-life and mathematics	"Different instruction styles, lessons, and activity ideas come to your mind if you think about innovative mathematics education. For example, I try to connect real-life in my lessons, activities, and examples. Firstly, I want to be used or create attention-getting lessons. So, I try to find real-life applications or real-life connections of my mathematics subjects." (P3)	7
Requires learning by doing and active participation	"… There are many practical advantages brought by technology, and these can be used in classrooms. Nevertheless, what matters more to me is that: the students should get involved in the process, not only following the lessons. I mean,	5

Table 4.1 Overall Information about the Teachers' Perceptions of Innovative Mathematics Education (Continued)

	learning by doing is an effective way to teach mathematics. I try to apply it as an innovative approach." (P11)	
Integrates technology	"Interdisciplinary, technology used... A lesson, not a lesson, an instructional plan that includes all of these. This comes to my mind. I mean, this is innovative. Because technology is developing day by day. We need to integrate technology into our lessons, within the bounds of possibility." (P1)	4
Activity-based	"When you say innovative mathematics education, I do not conceive a teacher as writing problems on the board and solving immediately without waiting for the students. I imagine a teacher who develops an activity with his students and solves context-based problems in it with his students. So, activity-based learning is an innovative approach in mathematics lessons." (P2)	3
Interdisciplinary (STEM education-modelling)	"Students mostly asked, 'What these concepts work in real life? Are they useful?" in mathematics lessons. If you connect mathematics and other disciplines, such as engineering and science, and present them with the use of mathematics, they understand the concepts deeper. So, integrating mostly science can be innovation in mathematics lessons." (P8)	3

Note. The number of total responses is greater than the number of the participants since some teachers' responses include more than one code/category. This is valid for the rest of the tables.

According to Table 4.1, it was found that the participant middle school mathematics teachers describe innovative mathematics education by explaining the characteristics of the innovation in mathematics instruction in their minds. Most of them interpreted this innovation by linking it with student-centered activities and real-life connections. They also mentioned the students' active participation, technology use, activity-based learning, and interdisciplinary connections as defining-factors of innovative mathematics instruction. These are characteristics of innovative mathematics education should have.

Almost all of the participating teachers described innovative mathematics education by expressing more than one characteristic of it. Their detailed responses based on the non-traditional educational approaches were given in Table 4.2. The table demonstrates the participant teachers' definitions of innovative mathematics education regarding its characteristics in terms of their theoretical understanding about it.

Table 4.2 Detailed Information about the Teachers' Perceptions of Innovative Mathematics Education

Pseudonym of the Participant / Teachers' Perceptions	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13
Student-centered		X	X	X	X	X	X	X	X		X		X
Connecting real-life and mathematics			X			X	X	X		X	X	X	
Requires learning by doing and active participation				X				X	X		X		X
Integrates technology	X									X	X	X	
Activity-based		X	X								X		
Interdisciplinary (STEM education-modelling)	X			X				X					

As seen in Table 4.2, all of the participants except P5 described the term "innovative mathematics education" by explaining more than one characteristic of it. For instance, integrating technology and being interdisciplinary makes mathematics instruction innovative in the eyes of P1. For example, P2 gives reference to being student-centered and activity-based for describing innovative mathematics education. These examples show that almost all of the teachers thought that having one of the above-mentioned characteristics of innovative mathematics education is not enough for being an innovative mathematics teacher or instruction.

4.2 Attributes of Implemented Innovative Mathematics Learning Activities

Throughout the interviews, the participants were asked to explain the characteristics features of the "innovative" mathematics activities they implemented with their students. The difference between this part (4.2) and the previous part (4.1) is participants' theoretical understanding of innovative mathematics education and their innovative mathematics education practices. In the previous part, the participant teachers' theoretical understanding and perceptions about innovative mathematics education were presented. In this part, the attributes of actual innovative activities that participant teachers have been doing will be presented. In brief, the teachers' perceptions of innovative mathematics education were mostly related to pedagogical features. The attributes of their implemented innovative mathematics learning activities have practical reflections of innovative mathematics education, and the current part includes more operational features than the previous part.

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, assessment techniques they used, and their resources while preparing for the activity. Table 4.3 demonstrates an overview of the participant teachers' responses to the characteristics of innovative mathematics learning activities below. The first column of the table shows the characteristics of the activities grouped under the main categories. The second column shows the sub-categories of the main categories since the characteristics of the activities implemented by the participants vary. Lastly, the third column of the table shows the frequencies.

Table 4.3 Attributes of Innovative Mathematics Learning Activities the Teachers Implemented with Their Students

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

Table 4.3 Attributes of Innovative Mathematics Learning Activities the Teachers Implemented with Their Students (Continued)

Information sources for teachers	The Internet	12
	Professional development seminars	8
	Books and articles	5

When the findings shown in Table 4.3 are examined, it is seen that the teachers used innovative mathematics learning activities mostly in the first two years of middle-grades. They used such activities less frequently in the higher levels of middle school, and none of them implemented such activities in their 8th-grade classrooms.

Teachers stated that they used these types of activities in three different contexts; (i) in regular classes, (ii) in the elective course of "Applications of Mathematics," and (iii) in student clubs they supervise. The participant teachers' overall tendency to use these activities was putting them into action in mathematics lessons. Also, one of the participating teachers (P1) talked about designing and offering a "Mathematical Modelling" course as an alternative to regular mathematics classes or enriching the content of the existing Applications of Mathematics course by adding it to carry out her activities. On the other hand, four teachers (P2, P5, P6, P10) stated that they worked with children on their out-of-class time since their schools had a student club on STEM and modelling.

The activities mentioned by the teachers were directly related to two mathematics content areas: (i) numbers and operations and (ii) geometry and measurement. The teachers asserted that they implemented the activities to teach or enhance mathematical knowledge about ratio, proportion, fractions, percentage, decimals, or calculation of decimals (numbers and operations), as well as polygons, circles, area, and measurement (geometry and measurement).

In the interviews, the teachers explained their innovative mathematics learning activities by referring to the curriculum objectives related to other disciplines such as science, technology, and social sciences. The most-mentioned characteristics of their activities developed or adapted by the teachers were designing a model and using educational technology. The activity implemented by P1 can be an example of the first common characteristics. She developed an activity called "Garbage Truck" to enable her 7th-grade students to enhance their knowledge of ratio-proportion, area of polygons, and volume of prisms by designing a garbage truck with waste materials. The activity implemented by P13 can represent the other most-mentioned characteristics of the activities. In her "Tree Planting" activity for 6th-graders, she asked her students to decide the most appropriate place on a given region on Google Map to plant trees, using their knowledge on polygons, areas of polygons, and measurement. She further integrated technology into her activity by asking students to use GeoGebra to divide whole land (in the shape of polygons) and calculating the planting area. The activities of other participants also involved the use of both technology and designing/modelling parts. For example, 6th-grade students of P10 applied their knowledge on ratio-proportion and area of polygons by designing houses, roads, bicycle roads, and green areas in the "Design a City" activity she developed. Her students made the drawings of their cities on the Tinkercad and then modeled them using waste materials. Another characteristic of the activities was presenting the mathematics subjects in the context of social and environmental problems to raise students' awareness. Designing nest for caretta caretta (P2), utilizing electric energy consciously (P3), preparing diet for people with diabetes (P6), making a plan for healthy nutrition (P7), estimating the damage of radiation leakage (P8), planning energy conservation (P9), preventing oil spill (P10), and planting trees (P13) were the contexts of the activities that lead students to become more aware of 21st-century problems.

Many of the teachers pointed out their tendency to select and use optimization problems in their activities. They remarked the restrictions they put for their students in the activities, such as using a minimum number of materials while designing, spending the minimum amount of money on material choices, or setting a model that meets all activity criteria. They indicated optimization as a characteristic of the activities by doing so. For instance, P12 talked about his 5th-grade activity, called "Airplane Model," and linked to ratio-proportion, area of polygons and measurement, to clarify the optimization of the given conditions. He said that "I asked my students to use limited cardboard and other materials and to build their airplane models considering the directions given in the activity." The directions were about using parallel lines, perpendicular lines, triangles, rectangles, etc., by restricting them with minimum and maximum numbers of the airplane's construction elements and logical scale model.

In addition, the interview data indicated that some of the teachers were in the tendency to link mathematical concepts to the middle school science concepts, such as boiling-melting (P4), planets (P8), and density (P10), in their activities. For example, P4 implemented an activity called "Snowflakes" with her 5th-grade students to improve their perspectives on symmetry and polygons subjects. Her activity includes forming a 6-sided snowflake and developing it by revising the 8-sided snowflake model after researching how snowflakes form and what their characteristics are. P4 stated that her students share their studies, and then they discuss their previous knowledge about boiling-melting concepts in science lessons. P8 linked her "Planets" activity to the ratio-proportion subject. She mentioned that the activity aimed to make students prepare a scale model of planets after students' research about the solar system, planets' size/radius, the distance between them, and their distance to the sun using the concept of ratio-proportion. P10 developed an activity called "Oil Spill" to enhance her 6th-grade students' knowledge of ratio-proportion by asking them to design barriers that prevent oil from spreading after a disaster. She mentioned they used saltwater, olive oil, and bottles filled with to represent seawater, oil, and barriers. Her students make a connection between density and ratio-proportion by using these materials and changing their amount to prevent oil spills by keeping barriers at a certain level.

Another characteristic of the teachers' activities was related to the average duration of their implementations. It was reached that the activities last almost 4 class hours on average. All teachers said that they implement almost all of their activities in multiple weeks, not in one week because of the class hour, approximately 45 minutes. For example, P6 mentioned that she implemented one of her activities for five weeks as 1 class hour of student club session per week. Similarly, P1 mentioned that she implemented one of her activities for two weeks as 2 class hours of applications of mathematics lessons per week. Also, teachers stated that some of their activities were implemented in one day as 2 class hours of mathematics lessons, depending on the nature of the activity and the level of their students. All of the participants reported that they preferred to group students during the activities in these class hours.

All of the teachers used observation and discussion methods as a primary means of assessment during the implementation of the activities. For example, P4 stated that she observed her students' performance during their group work using the observation checklist. Her checklist consisted of items such as engaging in group-work, making predictions, and testing their solutions. She stated that she graded her students' performance from 1 to 5 by observing them according to these items. Although P4 did not give feedback about the problems related to students' processes at first and let them learn by trying and discussing in their groups, P5 stated that she used the observation method too, and she gave feedback to her students when she realized something wrong in their studies.

In addition to the observation method, the discussions were also used as an assessment tool by all participants. For instance, P1 said that, during the activity, she asked open-ended questions to her students for understanding their learning process. She created a discussion environment according to her students' responses to enhance their learning and develop their critical thinking skills. This process indicates that she immediately used her assessment of students' thinking for formative purposes to improve students' learning during the activity.

Another means of assessment used by participant teachers during their activities were performance tasks. They used their activities as an assessment tool by asking students to demonstrate their knowledge and understanding in their working process and final product. To exemplify that the assessment process of the before-mentioned "Airplane Model" activity implemented by P12 can be given. P12 stated that he evaluated his students as learned and successful when they created airplanes using instructions and restrictions.

Peer rating was another means of assessment that was used by participant teachers during their activities. For example, P2 asked her students to evaluate their group-mates by using a rubric. She stated that she searched this rubric on the Internet, and it included items for scoring them according to their contribution to group work. Like in-group peer rating, she also used inter-group peer rating as a means of assessment. Her students made a presentation about the before-mentioned “Caretta Caretta Nest” activity. In this activity, her 6th-grade students design a nest for caretta caretta by searching sizes and living conditions of caretta caretta to prevent their loss of egg. She said that her students used the concepts of ratio-proportion, area of polygons, and volume of prisms in the design process. After completing the activity and designing the nests, groups presented their studies to other groups, and they were evaluated based on a rubric formed by P2. The rubric consisted of specific items for the activity, such as using a given whole area (in the activity sheet such as 50 m^2) effectively, designing nests properly for caretta caretta, and placing nests effectively.

Teacher-created paper-and-pencil tests were also used as an assessment tool, especially at the end of the activities. The test created by P7 and implemented after her before-mentioned activity “Healthy Nutrition” can be given as an example for the use of teacher-created paper-and-pencil tests. She asserted that she used this traditional assessment format to evaluate her students’ knowledge about rational numbers and ratio-proportion. These two concepts were the subject of the activity created for her 7th-grade students to enhance their knowledge about rational numbers and ratio-proportion by asking them to prepare a nutrition plan for themselves. The plan should contain how many carbohydrates, protein, and fat they need daily according to their body-mass index. Students calculated the amounts of these nutrients by choosing food (with calories) from the given menu. She stated that the paper-and-pencil test consisted of true-false, multiple-choice, and open-ended items ordered from easy to difficult. All the other teachers who used paper-and-pencil tests after their activities stated that they preferred to use these tools to evaluate their students' knowledge about the concepts in their activities, and the items in the tests were mostly taken or adapted from test books.

The last-mentioned assessment tool used by the participants at the end of the activities was exit cards. The teachers expressed that their exit cards included traditional items such as listing things their students learn or their feelings, discussing their learning level, and evaluating the lesson and their participation.

Lastly, the findings demonstrated that the teachers' innovative mathematics learning activities were taken or adapted from several sources, including the Internet (social media and educational websites), professional development activities they attended, and books & articles. Almost all of the teachers said that they follow professional groups of educators and mathematics teachers on social media and websites related to education to improve the quality of their instruction and to get inspiration for creating these types of activities. Most of them tried to attend in-service training conferences and seminars to be up-to-date mathematics teachers. Many of them stated their mathematics education books and journal articles as critical sources for investigating the ideas for innovative mathematics education. So, all of these were information resources for teachers to implement their activities. P1 used all of the mentioned sources and explained her resources as follows:

> I use my social media accounts for educational purposes. I follow the most popular groups of mathematics teachers and pages on Instagram and Twitter, and I made use of their experiences. I tried to adapt foreign mathematics teachers' activities to my classroom. I researched the activities on websites like Khan Academy, NCTM, and Girişimci Öğretmen. I tried to participate in in-service training organized by MoNE and conferences like Eğitim Teknolojileri Zirvesi, Matematik Öğretmenleri Paylaşım Zirvesi, Zeka ve Yetenek Kongresi. Thanks to these organizations, I met many mathematics teachers, and they shared their experiences. Also, I tried to read mathematics education books and articles to understand mathematical and educational concepts. All of these gave me the inspiration to implement these kinds of activities.

4.3 Emotion Perceptions During Innovative Mathematics Learning Activities

Middle school mathematics teachers were asked to describe their emotions as teachers while putting their innovative mathematics learning activities into practice. Their emotions were reported with sample quotations in Table 4.4. The table illustrates participant teachers' emotions during innovative mathematics learning activities grouped under main categories in the first column, sample responses of the participants as a representative of these categories in the second column, and frequency of these categories in the last column.

Table 4.4 Perceived Emotions of Teachers During Innovative Mathematics Learning Activities

Emotion	Example quote(s)	Frequency
Satisfied	"… Students are doing something on their own, designing or learning something at the end. They are happy when they do something. They discover the subjects. At those times, I feel like giving them a different point of view, and I feel pleasure, yes. … I feel the satisfaction of teaching them something; maybe this is what some people say occupational satisfaction." (P5)	8
Having fun & not boring	"I think that if I teach my lessons with pleasure, my students have fun in lessons. So, I make an effort to be joyful. "Sometimes, I am bored in lessons if I teach them, in the same way, the second time! … These activities allow me to diversify my teaching way, so this uplifts me, and I have fun." (P6)	6
Motivated	"These activities are motivated me incredibly. For example, my students are happy if they use technological tools or if their design works. Don't these motivate a teacher? My students' reactions motivate me to implement such activities." (P13)	5

Table 4.4 Perceived Emotions of Teachers During Innovative Mathematics Learning Activities (Continued)

Effortful	"I get tired more since these lessons require observing students more in their groups. Also, I get tired while planning these activities. I research on the Internet or read books to find activities." (P12)	5
Excited	"… Implementing such activities motivates students to learn mathematics. Seeing their motivation, participation, and effort excite me. I also get excited while they test their prototypes or solutions." (P2)	3

As seen in Table 4.4, many of the teachers had positive emotions such as being satisfied, having fun, motivated, and excited while implementing innovative mathematics learning activities, and almost all of these emotions were aroused according to students' reactions and emotions. To put the teachers' emotions more explicitly, they feel satisfied when their students' learn the topics they covered in the activities and correspondingly when their students became happy during the activities. They felt like enjoyable teachers and do not get bored during the activities since they play an active role and interact more with their students. They are motivated more in the lessons they use such activities because of their students' positive reactions to the activities 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 for learning and participating during the activities.

Some of the teachers identified their emotions as tired, which depends on their role in these activities. More clearly, they feel tired since planning and implementing such activities requires more effort than their traditional lessons. So, it can be said that teachers' feeling of "being tired" was not used in a negative way; on the contrary, it meant that they used activities that require their effort, namely "effortful."

4.4 Perceived Effects of Innovative Mathematics Learning Activities on Students

The participating teachers were asked to explain 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. The findings related to the effects on students were given as follows. Table 4.5 summarizes the effects of innovative mathematics learning activities on students as categories and frequencies. These effects were expressed as influencing their students' attitudes, awareness, skills, and learning positively by all participants and collected under five main categories.

Table 4.5 Perceived Effects of Innovative Mathematics Learning Activities on Students

Main Category	Frequency
Changes in Attitudes and Awareness	13
Effects on 21st-Century Skills	13
Effects on Affective Skills	13
Effects on Learning	12
Effects on Psychomotor Skills	8

4.4.1 Changes in Attitudes and Awareness

All of the 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. Table 4.6 provides information about changes in students' attitudes and awareness by organizing it under six categories and giving their frequencies.

Table 4.6 Perceived Effects of Innovative Mathematics Learning Activities on Students' Attitudes and Awareness

Changes in Attitudes and Awareness	Frequency
Improved awareness about occupations	10
Improved awareness of social and environmental issues	8
Enthusiastic participation in lessons	4
Less occupational stereotypes	3
More persistence to learn mathematics	3
Realizing the connection between real-life and mathematics	3

The most common comment of the teachers was that students' awareness about occupations and possible carrier choices were improved. They referred to the interdisciplinary nature of the activities as a leading factor for finding an opportunity to learn disciplines and related professions. For instance, P6 addressed the adolescence period of her students as "I don't know whether these activities directly affect their life or not, but I observe their indirect effect. You know, their ideas, aims, abilities, or hobbies are shaped in middle school years. They are able to know themselves and discover their potentials as much as getting new and more knowledge [disciplines], and then they can choose what they want to be." (The square brackets in this sentence are used and will be used after refer to expressions added by the researcher according to the interviews.)

P3 supported this by focusing on mathematics:

> If the subjects [disciplines and real-life applications in the activity] get their attention, they may consider that they are interested in them. For example, they may say that "Mathematics subjects don't attract my attention. I will not study on science-mathematics." On the contrary, they may realize their interest in mathematics with real-life connections in the lessons, and they may tend to be studied in engineering fields.

P12 strengthened these views by sharing his experiences:

> [In his designing and an optimizing activity called Airplane Model], I realized that students searched what engineers and architects do. Later, one

> of my students said he wanted to be a doctor before, but now he wants to be an engineer to investigate real-life applications.

Hereinbefore, one of the characteristics of innovative activities of the teachers were being related to social and environmental issues to raise students' awareness. As a reflection of this characteristic, many of the teachers stated positive change in their students' awareness of social and environmental issues. The most remarkable changes in students were trying to eat healthy foods and outgrowing junk foods after the "Balanced Nutrition" activity (P3), to research the adverse effects of nuclear energy, and watching the nuclear energy plant process in Turkey after "Radiation Leakage" activity (P8), and turning the lights off after "Energy Conservation" activity (P9).

Some of the teachers shared their observations about students' desire to participate in lessons with student-centered activities depending on the increase in their affective factors such as motivation, interest, and attention. They observed that their students participated in mathematics lessons more and ambitiously when they implemented these activities. P4 exemplified this finding by comparing her innovative lessons with direct teaching ones:

> They are interested in such activities. I realized that they participated in these lessons [lessons implemented these types of activities] more. I mean, maybe %50 or %60 of the students participate during 40 minutes in regular lessons. However, they participate in these activities for all 40 minutes, and they contribute to the lesson with me.

P11 emphasized the students' desire to respond to her efforts in the lesson and stated that "Students show respect for the effort. They say that 'You prepared these and made an effort for us.' They appreciate and want to give a response to this by participating in lessons. They are involved in the lesson."

Although all of the teachers mentioned such positive changes in their students' participation in both regular lessons and lessons with innovative activities, they strongly emphasized the quality of participation in lessons with these activities. P5 elaborated her students' participation in other mathematics lessons by attributing it to the positive effects of her innovative activities on her students:

> You can provide that all of the students attend lessons. They do not only listen but also write things on the board and pass them on to other subjects. They play an active role in their learning process and participate more in these lessons. Also, they participate in my regular lessons more since they realize that they get into mathematics and understand it. I think that their motivation and interest in mathematics increases in my activity-based lessons, and then they participate more in my other lessons thanks to that motivation.

Another finding was associated with students' attitude changes related to increased social awareness and minimized occupational gender stereotypes. For example, P1 indicated that she decided to implement the "Bridge" activity for raising awareness of gender issues. She continued her words:

> At first, I explained that they would design a bridge with materials and use mathematics, science, and design disciplines. However, many of my students said that 'This is construction and not suitable for girls.' Both boys and girls [said this]. After starting the activity, they realized that their opinion was not right. I talked about my female engineer friends and how they graduated successfully. Now, my female students started asking questions about engineering to the school counselor, and my male students do not think like that [Some certain professions are only for females; they do not have all types of jobs.]. I always try to emphasize gender equality, and this kind of activity is suitable for imposed it on them.

According to some of the teachers, their students demonstrated increasing effort to learn mathematics, thanks to their activity-based lessons. The activities helped them to strengthen students' persistence in learning. For example, one of the students of P11 asked her to advise a book for searching related mathematics subjects and learning concepts more in-depth. The teachers interpret these kinds of changes in students' attitudes towards mathematics as their increasing effort for mathematics lessons.

Lastly, three teachers (P1, P3, P7) addressed the decrease in students' usual questions: "How these concepts work in real life?" They stated that students no longer ask such questions and realize the mathematics in real-life. Instead of asking such questions, they search for mathematical applications on the Internet and even share their findings with their teachers and classmates. So, the teachers indicated that realizing the connection between real-life and mathematics was an effect of their activities on students.

4.4.2 Effects on 21st-Century Skills

The interview results indicated that the teachers 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, research, creativity, and curiosity. The teachers argued that they observed improvements in their students' such 21st-century skills. Table 4.7 summarizes these findings by demonstrating the six categories of effects of students' 21st-century skills and their frequencies.

Table 4.7 Perceived Effects of Innovative Mathematics Learning Activities on Students' 21st-Century Skills

Effects on 21st-Century Skills	Frequency
Collaboration skills	10
Communication skills	6
Problem-solving skills	5
Critical thinking skills	4
Creativity & curiosity	4
Research skills	3

Most of the teachers mentioned that students were developing collaboration skills due to group work in the activities. Since the teachers grouped students in the lessons, and the activities consisted of many tasks to accomplish through teamwork, their students collaborated. P9 stated her ideas on this issue as follows:

> Most of our students are only-child in their families, and they tend to be self-centered. Working in groups is an advantage for them to be more cooperative

> since they make work sharing. They realize that there are some people you may need their help or vice versa. They may need your help. So, they learn how they collaborate with others.

P10 shared her experiences about the same issue by asserting the differences in students:

> Students have different interests, and they are at different levels of success. Getting them together heterogeneously based on their differences makes them collaborate. Thanks to the collaboration, they can learn from each other.

P11 emphasized the importance of effect on students' collaboration skills by mentioning their future career:

> Since they work in groups during such activities, they learn collaboration. I think they understand that they cannot always work with people they want in their lives, or they cannot always do what they want in their lives.

In addition to this, some of the teachers mentioned the development of their students' communication skills by referring to group-work characteristics of their activities as development in collaboration skills. They mentioned the development of self-expression while communicating with group mates (P4, P7, P12) and improvement in respecting their ideas by listening to each other (P5, P9, 10).

According to the participating teachers, other 21st-century skills-related-effects of innovative mathematics learning activities were developing problem-solving skills (P3, P4, P15, P9, P12), developing critical thinking skills (P1, P3, P6, P9), improving creativity and curiosity (P1, P2, P4, P6), and improving research skills (P1, P2, P6). However, their comments were limited to only one or two sentences like "During the activities, their problem-solving skill develops." Since their words were undetailed the development process of these skills, the last four findings reported that.

4.4.3 Effects on Affective Skills

All of the teachers stated that these activities had positive effects on their students' motivation, attention, self-confidence, and sense of achievement. The findings are summarized in Table 4.8.

Table 4.8 Perceived Effects of Innovative Mathematics Learning Activities on Students' Affective Skills

Effects on Affective Skills	Frequency
Increasing motivation towards mathematics	11
Attracting and gaining attention	9
Increase in self-confidence	3
The sense of achievement	2

Although almost all of the teachers mentioned an increase in students' motivation towards mathematics, none elaborated on this point. They commented considering the whole process of their activities from planning to evaluating. However, some of the teachers indicated the persistence of their students' motivation after their activities, like the increase of it during the lesson-time. The response of P4 can clarify this persistence:

> My students' motivation increases towards my lesson when I apply such activities. Later, they asked questions like "When will we do them again?" They said that "We liked problems, please plan similar activities." all the time we met. I think that they are highly motivated even after the activities.

Also, P1 referred to a similar motivation-effect on her students and their design revisions in the "Bridge" activity by saying, "They are motivated. They told me their upgraded-plans to design bridges even weeks later."

The other perceived positive effect of the activities on students was paying more attention to class. Nearly all teachers observed that their students showed more attention in their innovative lessons than their traditional lessons. For example, P11 stated that the use of materials in those lessons might be a reason for this; "Entering the classroom with the material in your hand or requesting them materials for the next lesson attract their attention instantly." P3 explained her practices on the same subject by emphasizing current issues, namely 21st-century problems:

> I tried to choose current issues as the context of problems in my activities. Firstly, I want to find attention-grabbing subjects and think that "Which subjects draw my attention?" For example, I used electricity consumption and healthy nutrition in two of my lessons as contexts. These helped me to catch students' attention.

Some of the teachers added self-confidence on effects related to motivation and attention in the light of their experiences. P5 shared her observations by mentioning the process her students experienced:

> Students have the self-confidence to do something. These activities increase their self-confidence. I mean, first of all, they react as "How do I figure out this?" or "I cannot do it." After realizing they can solve, model, or draw, whatever it is, they have self-confidence.

In addition to these, two of the teachers talked about the sense of achievement as an effect of their activities on students. For example, P12 expressed his experiences as "These activities are more effective than direct instruction, since students realize they can achieve. My students said 'I did this' at the end, and they got a taste of achievement."

4.4.4 Perceived Effects on Learning

Table 4.9 given below presents the perceived effects of innovative mathematics activities on students' learning.

Table 4.9 Perceived Effects of Innovative Mathematics Activities on Students' Learning

Effects on Learning	Frequency
Leading to meaningful learning/learning deeper	9
Increasing academic achievement	7

It is found that almost all of the teachers highlighted the improvement in student-learning of the concepts in the activities and an increase in students' achievement in mathematics. Many of them expressed that students learn mathematical subjects deeper, thanks to these activities, since they are related to real-life and other disciplines, and students are active. So, mathematics becomes meaningful to students. For example, P12 asserted his opinion about this effect:

> I aim to teach mathematics with the reasoning behind it in all my lessons. Students learn by doing, and they are responsible for their own learning in the activity-time. Learning by doing and making reasoning are effective to ascribe a meaning to mathematics. I think that my students learn meaningfully.

Like P12, P4 referred to meaningful learning effect:

> In my opinion, students establish a relationship between mathematics concepts and other lessons such as science. Also, they realize the connections between subjects. They understand meaningfully. For example, my 7th and 8th-grade students can solve the problems if we ask the same problems in the activity that I implemented when they were in 5th grade. Because they do not forget the concepts, they really learned. [She gave this example since she mentioned that she observed many of her students cannot remember and learned concepts and easily remember the solution methods of problems. However, she emphasized that her students can remember the concepts and find the solution even if after years since they "really" learn subjects thanks to these types of activities.]

P2 took it one step further by combining it with an increase in her students' academic achievement:

> Implementing these activities is better than direct teaching since students internalize subjects more, understand more meaningfully, and research more. This active participation of students brings academic achievement. Some of my students got better marks after the activities.

P6 associated an increase in students' academic achievement with their growing interest in lessons. She said that "These type of activities increases students' interest. Their academic achievement increases in direct proportion to their interest according to my experiences."

4.4.5 Effects on Psychomotor Skills

It was reached that the teachers implement mostly modelling or designing activities, and they stated that they observed the development of their students' psychomotor skills. P4 exemplified the development of psychomotor skills of her students by sharing characteristics of her modelling activities. She stated that "Such activities directly affect students' psychomotor skills. Drawing geometric shapes, to measure their areas or angles, to cut materials, etc., are important."

Similar to P4, P12 emphasized his experiences by comparing grade levels: "Yes, the activities influenced psychomotor skills. But I think the activities have more effect on 5th and 6th-grade students' psychomotor development."

4.5 Enablers of Providing Innovative Mathematics Learning Activities

The middle school mathematics teachers were asked to describe factors that support them in the process of implementing activities from the very beginning to the end. They 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 them to plan their lessons. Table 4.10 presents an overview of the enablers brief explanation of each.

Table 4.10 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

As seen in Table 4.10, collaborating with colleagues was the most-mentioned factor supporting teachers in their activities. Teachers touched upon the significance of exchanging ideas with their colleagues. They did not narrow down this support with mathematics teachers, and they talked about their idea-exchange with teachers from other disciplines such as science and technology. P6 call for her colleagues' support in the planning process of activities:

> I called all of my colleagues, and we talked about my lesson plan. I asked them whether this plan is suitable for our students or not. I mean, I got their opinion. "Is this objective appropriate?" "Do they match with each other?" "Did you cover these topics?" "Do you think students can understand?" etc. I asked them many questions. Their answers helped me to shape the lesson.

Like P6, P2 stated the support of her colleagues played a big part in planning activities, and she added that her colleagues continued to support her in implementing activities:

> While working on activities, I mentioned my activity ideas everywhere. "Is this a good plan?" "What are your opinions about it?" "I will implement this. Is it okay?" I asked them nonstop. We confer on our activities and the way of teaching with my colleagues. Their ideas and feedback help me to shape my lesson. Even they came to my class to observe the lesson while implementing it since they care. After that, they gave me feedback like "Students were bored in this part.", "You should add some new parts." etc.

Also, P12 indicated that ideas and implementation experiences of his colleagues about his activity have great importance on revising his activities in a better way:

> For example, they [other teachers] realized my students' models or activity sheets while they passed through the corridor or witnessed conversations between my students and me. Then they ask, "What did you do in the lesson?" "How was this activity?" or "I want to implement it with my students. Can you explain it in detail?" Then s/he use it directly or after adapting to her/his students. Then we discuss our implementation process, students' reactions, or classroom management. Exchanging our ideas and experiences makes activity better. We use such activities with their best version later. By the way, I also use their activities, and the same process begins.

In summary, participating teachers could refine their activities' planning, implementing, and revising processes by collaborating with other teachers, exchanging their ideas and experiences.

The second most-mentioned factor supporting teachers in their activities was receiving support from school management. Many of them interpreted it as their encouragement to develop themselves. For instance, P11 said that "The management support us whatever we want to implement. They are open to taking action and receptive to develop such plans. So, I feel lucky."

P10 shared her experiences by including financial support of school management:

> Our school management is guiding teachers in career development. They encourage us to participate in teacher training. Also, they support us in providing materials since we sometimes need technological tools in our lessons.

Similarly, P2 asserted the positive effects of her school management team on her lessons:

> School management receives our plans favorably. They support us. Maybe the most important factor that allows us to teach lessons with activities is their perspective. They provide us with materials used in activities or arrange student club hours and the club classes according to our programs. The school principal is open to new ideas and applications.

In short, the school management teams' vision, moral and material support, and useful educational points of view affect teachers' planning and implementing the process of the activities positively.

The third most-mentioned factor supporting teachers in their activities was receiving positive feedback from parents. Although many of them indicated that parents have no effect on their instruction, some stated parents' positive views on their activities. They attributed their feedback to students' interest and motivation in their activity-based lessons. P3 stated that:

> I heard from parents that "Our children love you so much. Their interest increases towards mathematics." They know what we do in lessons, and they are aware of it. I mean, the more interest of their child in the lesson, the

> happier the parents are. So, such words support me. … Even if such activities are effortful, I want to implement more activities, and I believe that I can.

P13 explained her experience on the same subject as follows:

> Parents know my teaching style. Children mention about lessons. In one of the parents' meeting, I observed that parents were more interested in such teaching, and they were excited. They asked me to give some details about our mathematics activities, and they said some supportive things for me by putting an increase in their children's interest, motivation, and achievement forward.

Like P3 and P13, P4 exemplified positive feedback from her students' parents by saying, "They know my teaching process. One of them said that 'Your effort for our children is very important.' Their such affirmative comments about my activity-based lessons encourage me."

Briefly, receiving positive feedback from parents based on students' interest in mathematics lessons contributes to teachers' self-efficacy positively, and they see their activity-based lessons as more valuable.

The fourth most-mentioned factor supporting teachers in their activities was thinking about students' possible questions. Teachers pointed out the importance of implementing activities with well-designed plans and having full knowledge of their activities. Since their activities included modelling, designing, using technology, or knowing other disciplines, thinking of themselves as their students and detecting their possible questions and reactions increased the quality of their instruction. P8 exemplified this factor by saying:

> I have to be prepared well for those lessons, and I need to know mathematics, technology, or science concepts more than students. If I use Scratch, for example, I have to learn it before students and master it. Because such things are new to me. I feel more comfortable in those lessons I planned all things before.

P6 said "I ask myself all possible questions that addressed me during the activity and try to find answers. Because teachers should know the answers or have an idea about what they do to lead students."

Also, P3 indicated her first step to the activity planning process was taking her students’ possible questions into consideration:

> I write the imaginary flow of my lessons. I prepare lessons by thinking, “What can I say when they say …?”, “They can have difficulty on this point, how can I overcome?” or “What they should know before the activity?” Shortly, I try to find my students’ all possible questions and prepare myself. I try to find possible answers to their possible questions according to my knowledge about their characteristics and way of thinking. Then I learn an application, prepare a backup plan, or find a video about our concept. It depends on my estimations about questions. For example, if I decide that the activity is not suitable for my students, I do not use it until they are ready.

In brief, it can be said that thinking about students’ possible questions during the implementation process of the activities enable teachers to plan their lessons effectively. It promotes their qualifications as teachers since they learn new things to answer their students’ possible questions. Also, they set goals about their activities more completely since they think about their students’ ways of thinking and possible difficulties.

The fifth most-mentioned factor supporting teachers in their activities was receiving positive feedback and reactions from students. They found their positive feedback and reactions as the driven force behind their motivation. P5 elaborated this finding as below:

> They asked questions like, “When will we do them again?” They said that “We liked problems, please plan similar activities.” all the time we met. I think that they are highly motivated even after the activities. Their reactions motivated me to implement such activities again.

Besides teachers’ increasing motivation after their students’ positive feedback, they implemented more activities. Experiences of P3 can be given to exemplify it:

> They want more activity-based lessons after all of our similar lessons. When they meet with different things in my instruction and become more active, their eyes shine, and they listen to me enthusiastically. Even one of them said that “You can teach mathematics even in our music class hours.” I heard for the first time! Math lesson instead of music lesson…Their reactions like this make me happy and motivate me. I realized the effect on them, and I said that “I will use these activities more.”

Shortly, receiving positive feedback and reactions from students enable teachers to be more motivated towards their professions. It can also be said that it contributes to teachers' self-efficacy positively, and they see their activity-based lessons as more valuable, like receiving positive feedback from parents.

The last most-mentioned factor supporting teachers in their activities was talking with an expert from different professions. The teachers touched upon briefly that they got help from an electrical and electrics engineer for learning technological tools she used (P1), an architect for making relating mathematics and real-life (P2), and a food engineer and environmental engineer for enhancing the quality of the context (P8). The electrical and electrics engineer friend of P1 enables her to learn Arduino by teaching basic knowledge about its hardware and software. She mentioned that she planned to use it in her activity and then became more skilled in Scratch with the help of her friend to be able to understand the logic of programming and coding. The architect friend of P2 enables her to learn Sketchpad by teaching her the basics about it. Learning Sketchpad and fundamental design principles from a professional made her implementation and evaluation process more effective. Also, she wanted to learn regulations about architecture in Turkey and add them to her activity to make it more realistic. The food engineer friend of P8 enables her to gain basic knowledge about diets such as healthy nutrition, balanced nutrition, and types of nutrients. P8 stated that preparing her activity with the help of an expert enhanced her activity quality, and the activity became more precise.

4.6 Barriers in the Process of Innovative Mathematics Learning Activities

The middle school mathematics teachers were also asked to describe the difficulties or barriers they encountered in the process of innovative mathematics learning activities. Their difficulties were grouped under four categories: (i) time, (ii) students' learning habits and classroom learning culture, (iii) work environment, and (iv) preparing activities. Table 4.11 showed these categories and their sub-categories with the frequencies of the difficulties encountered.

Table 4.11 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

4.6.1 Barriers Related to Time

Almost all of the teachers were challenged in having limited implementation time for the activities by asserting the necessity of practicing the mathematics curriculum objectives and preparing students for national exams. The most-mentioned barrier related to time was synchronizing the lessons with the curriculum schedule. For example, P13 reflected her time constraints for covering the curriculum by emphasizing the requirement of teaching subjects at a particular time:

> Time is a huge problem for me. This is one of the reasons for feeling pressured for time in the implementation period. In the meantime, the academic calendar is progressing. You have to go parallel with the curriculum and cover subjects in it.

Similar to P13, P2 mentioned that she had great difficulty in finding time for activities in class hours because of the heavy schedule of the curriculum and due to this, condition implementing the out-of-class solution of time constraint:

> Our curriculum is intensive, and we don't have sufficient time for such activities. I implemented my activities by making time in the student club. I mean, I have no chance to spare four hours to activities from my lesson hours.

Some of the teachers remarked the high stakes exam that students take at the end of middle school to get into high-school as an obstacle to implement their activities as they planned. They indicated the need for more time by sharing their experiences as shortening the time of activities. For instance, P4 identified this difficulty with parents' expectations on procedural fluency of students in exams:

> Most of our students are successful in lessons, and their parents focused on the exam [high-school entrance exam]. These kinds of exams are a reality in Turkey. Parents ask teachers to solve questions all the time. Solve problems, solve problems… Our children will be able to solve them fluently. We have pressure originated from exams.

P5 shared her experiences related to the same difficulty by asserting the expectation of older students:

> We also try to prepare our students for the exams. So, such activities lose their value in the eyes of students. This is valid, especially in higher grades, since their time is running out for the exam.

To sum up, teachers perceive time as a barrier to implementing their innovative mathematics learning activities in two ways, covering the curriculum and accordingly preparing their students for high stakes exams.

4.6.2 Barriers Related to Students' Learning Habits and Classroom Learning Culture

The teachers encountered difficulties arising from traditional ways of learning and teaching. Nearly all of them criticized students' learning habits and classroom learning cultures, such as being familiar with teacher-centered instruction and lack of teamwork experiences, and difficulty in classroom management generating from these habits and culture.

Many teachers pointed out students' common experiences of studying in teacher-centered lessons and not being familiar with lessons; they are active learners. For example, students of P1 supposed that they were playing in mathematics lessons, and P1 struggled to eliminate their point of view:

> Students were accustomed to lessons taught with direct teaching. It was hard for me to impose my way of teaching on them. They saw activities like play, and it turned to "What we will play in this lesson?"

P4 explained her students' attitudes towards the same issue by mentioning their lack of responsibility for their own learning:

> Students asked me everything, and they were so used to asking questions. They needed approval. At first, they did not read even the activity sheet. They could not understand their roles in the lesson and what I expect them.

In addition to being familiar with teacher-centered learning, students tended to work individually as one of the characteristics of the traditional instructional methods. But since the teachers implemented their activities by grouping students, their tendency to work individually was a challenge for the teachers, namely lack of teamwork experiences. P8 exemplified that with her experiences:

> The most common difficulty I experienced was adapting students to group work. They are unaccustomed to working in groups. They generally work individually. When I said, "Let's work in groups!" they preferred to work with friends at the same success level. … So, asking them to work with their friends in groups was difficult.

P10 explained her difficulty in the same subject as given below:

> Grouping students is a challenge for me. They always want to work with their close friends or desk mates. But I care for making heterogeneous groups. They sometimes complain about their group mates during the activity, if they don't work with their close friends.

Lastly, some of the teachers had difficulty in classroom management because of the student-centered nature and working them in groups characteristic of their activities.

They mentioned the need for guiding groups, their tendency to talking other than mathematics with each other in groups, and the possibility of making noise and added they were tired more in those lessons. P7 said that:

> Since students play an active role, work in groups, and are in middle school ages, I need to be more well-controlled. They may pay attention to different things than our activity or make a noise. … So, you need to be careful in classroom management.

Moreover, P12 referred to his role in the activity time and classroom management difficulty by saying, “Sometimes classroom management is a challenge for me. For instance, I became ill after one of my activity-based lessons. I talked loudly and talked with all groups so much. The teacher leads students more in these lessons, I think.”

In conclusion, teachers perceive their students’ learning habits and classroom learning culture as a barrier to implementing their innovative mathematics learning activities since the students are familiar with student-centered instruction and have limited group work experiences. As a result, teachers are having difficulty in classroom management.

4.6.3 Barriers Related to the Work Environment

Many teachers pointed out the conditions in the work environment as the difficulty they encountered. These conditions were grouped under three sub-categories: (i) having too much workload, (ii) lack of equipment, and (iii) destructive criticism of colleagues.

Five of the teachers referred to their workload as an obstacle to plan or implement their activities. They asserted their other works in the school as a limiting factor for their time. For instance, P6 enlighten her difficulty related to workload as not to allowing enough time for her activities:

> These types of activities require many hours of research and planning. However, my workload inhibits me from making time for that. I have to

> prepare homework, exams, or other study aids for my students. Insufficient time is a disadvantage.

P9 stated her dissatisfaction related to the workload by mentioning her working hours:

> Activities necessitate heavy preparation, and planning them takes time. It is not that "Okay, I searched in minutes, and found it." Deciding on the subject or adapting for students really take time. However, working hours prevent the process. I work 25 hours a week in class and paperwork, teachers' meetings, and parents' meetings excluded. So, I research out of working hours. You need to make a sacrifice.

Some of the teachers complained about the lack of equipment in their schools. They mostly mentioned their need for manipulatives, technological tools, or places designed for activity-based instruction. For instance, P3 said that "We have inadequate material used in mathematics lessons. Sometimes, our material needs are not met and treated as nonessential because of financial concerns."

Although collaborating with colleagues was marked as a supporting factor for teachers while planning or revising the activities, some teachers suffered from their colleagues' negative point of view to their teaching style. These teachers touched on destructive criticisms of their colleagues towards the activity-based instruction. P1 reflected her experiences affect her negatively and cause disappointment by criticizing the professional perception of her colleagues:

> When I collected waste materials in the schoolyard to use in my activity, other teachers saw and asked what I do. I explained my plan, and then they commented as "So, you will play with children." Then they assumed me as a "playful teacher" … They always asked me the same question: "Why do you work so hard?" They added, "You will not earn extra income. Teach your lesson and solve questions in the book." … I cared about their mentality at first, but now I don't care about them.

Similar to experiences of P1, P3 asserted her confusion and disappointment after negative comments from her colleagues about her way of teaching:

> I try to diversify my instruction with materials, activities, or others. I prepared an activity, and one of my colleagues saw it in the teachers' room and asked me: "Why do you put effort into these?" I replied to him by saying, "Because

> of my students. I want to take their attention and teach mathematics better." Then another teacher heard our conversation, and both of them grumbled as "Who cares! If they are willing to learn, they will understand. Such materials do no matter. You are tiring yourself in vain!" I was astonished and could not say anything. Then I thought I should try to make my instruction better for my students, despite some of my colleagues' "teaching perspective."

In summary, teachers perceive their work environment as a barrier to implementing their innovative mathematics learning activities because of their workload, inadequate equipment, and colleagues' negative comments about their instructions.

4.6.4 Barriers Related to Activity Preparation

According to nine of the teachers, they faced difficulty while preparing their activities because of not being able to integrate other disciplines into mathematics smoothly, having a lack of knowledge and experiences about these types of activities, and not being able to simplify complex concepts for students easily.

Teachers tried to establish connections between mathematics and subjects/objectives from other disciplines such as science, technology, and social sciences, hereinbefore, as one of the characteristics of their activities. At the same time, they had difficulty in integrating mathematics and other fields in a proper context. P10 mentioned her difficulty as the following:

> Connecting mathematics with science concepts challenged me. I tried to present the task-related ratio and proportion in the science context. I read the science curriculum and science textbook. But I had no idea. Then I came up with an idea related to environmental pollution while watching a documentary. The integration part is a problem if you want students to understand real-life mathematical applications.

Some teachers emphasized their lack of knowledge and experience by saying returning them as an obstacle for planning their activities. P5 elaborated on this obstacle by sharing her question marks:

> Yes, I implemented, but I did not know what I should do at first. I did not know how to proceed with the lesson, watch the process, lead the students,

> and convey concepts to them. I tried to learn them. … Are they resolved? I don't know. I still research.

Besides, the teachers had difficulty in revising their ideas according to the levels of their students. They made an effort to simplify complex concepts for students in the preparation stage of the activities. P12 addressed this difficulty by saying, "Working in higher grades is easier, since the concepts are more. But I work more on simplify tasks for younger students. Revising activities for them is challenging."

P2 shared her difficulty on the same issue by exemplifying her planning stage of one of her activities (designed for 6th-grade students, called "Smart City," and related to ratio-proportion, area of polygons, measurement, and environmental issues):

> I planned first using the Arduino set to link solar energy if one of the groups wants to add it. I also planned dwelling on the amount of produced energy; factors affect its change and mathematical calculations. However, I realized that students need to know trigonometry for calculating solar power. I had a problem in making the activity simpler considering students' level.

Briefly, teachers perceived the preparation process of the activities as a barrier to implementing them for three reasons: having difficulty in integrating mathematics and other disciplines, having inadequate knowledge and experiences about them, and having difficulty in simplifying concepts according to the level of their students.

4.7 Teachers' Suggestions about Innovative Mathematics Learning Activities

The participants were asked to express their suggestions about innovative mathematics learning activities by considering their supporting factors and difficulties. They gave suggestions to three educational stakeholders: (i) teachers, (ii) MoNe, and (iii) universities. A summary of their suggestions is given in Table 4.12.

Table 4.12 Teachers' Suggestions about Innovative Mathematics Learning Activities

Main Category	Sub-category	Frequency
Suggestions to Teachers	Researching to keep themselves up-to-date	11
	Knowing students' characteristics/interests	7
	Observing and leading students	5
	Becoming persistent in implementing	5
	Implementing the well-known, similar activities	4
	Getting opinions of others	4
	Learning a foreign language	3
Suggestions to MoNE	Simplifying the mathematics curriculum	6
	Providing training and resources for teachers	4
	Putting sample activities in the curriculum	4
Suggestions to Universities	Providing training and resources for teachers	2

4.7.1 Suggestions to Teachers

The teachers had many suggestions for other teachers who may want to use innovative activities with their students. The participants' suggestions mostly reflect the implications of their own experiences with such activities. The suggestions were mostly related to the perspectives and characteristics of the teachers who intend to implement and the characteristics and attitudes of the students.

A great majority of them dwelled on the importance of improving oneself by researching the latest developments in education, especially in mathematics education, to keep themselves up-to-date. To become innovative teachers, they pointed out the advantages of attending conferences, reading research studies, books about mathematics education, etc., which were their information sources, as mentioned in the previous sections. For example, P1 said, "They should always read to follow what is new in teaching, what will happen in education." P8 supported P1 by saying, “They should change their perspectives, develop themselves, and be open to innovation. They should think and realize that their knowledge and practices is becoming insufficient and invalid day by day. Researching is effective to catch the trends.”

Many of them emphasized the value of taking students’ characteristics and interests into consideration. They mentioned that learner characteristics could not be ignored since teachers do these activities for and with them. Their advice laid weight on knowing students’ success level and socioeconomic status (P4), abilities and needs (P2), and interests and learning styles (P11) while planning their lessons.

Some of them recommended the implementation process of the activities by asserting teachers’ big responsibility in guiding students. Their advice was about observing and leading students in the lesson, and some of them likened their advice to be on the alert. P3 detailed her advice, as indicated below:

> I think they need to observe. They cannot say, “Okay, children, this is your activity.” and stand back. They should be careful and guide their students. … New questions of students may come in sight. If they don’t answer them or lead to find the answer, students are confused. … They should observe their students.

Another recommendation of the teachers was related to their reactions to challenges in the process of the activities. This recommendation was mostly put into words by teachers who had difficulty in the work environment. They referred to the importance of becoming persistent in implementing such activities, whatever keeps them back. For example, they mentioned they learned to stand firm across criticism of colleagues (P1) and lack of equipment (P3). They suggested that teachers should never give up since they experienced the positive effects of their persistence.

A few of the teachers thought that starting from well-structured activities helps teachers understand their nature. They reported that implementing the well-known, similar activities at the beginning is beneficial for them. For instance, P7 shared her suggestion by citing her experience:

> Firstly, I read books and noted sample activities, and then I implemented them. Investigating the structure of the tasks on one's own is important. Since they were implemented before by others, they included feedback or tips. So, they should analyze sample lesson plans on the Internet or in books.

Some teachers remarked that they would like to receive advice from other teachers to become more ready for their lessons. So, their suggestion of getting opinions of others originated from their experiences on lack of guidance. P5 addressed her first activity by saying that:

> I expected a person who tells me what is okay or what is wrong in my activity. If you know this, you teach your lesson better. … Asking about lesson plans with experienced teachers is essential. They remark points to consider. Teachers should talk with other teachers for being able to be prepared. I think preparation is half of the process.

P9 supported the views of P5, and she referred to the importance of peer learning as getting a second opinion:

> I consider peer learning as significant. I mean, asking other teachers questions like "Do you have any suggestions?" "Do you like these problems?" etc. … They should be open to taking the ideas of others. Because developing activities is highly related to their comments.

The last suggestion of the teachers (P4, P9, P12) to other teachers was learning a foreign language. They stated they see the benefit of knowing English while researching the resources. They recommended learning a foreign language, especially English, by pointing out the vast number of English resources and the limited number of Turkish ones.

4.7.2 Suggestions to MoNE

As mentioned earlier, the teachers had difficulties related to time constraints for covering the curriculum and their lack of knowledge and experiences. They recommended MoNE by remarking on their demands to overcome these difficulties. Their recommendations that are formed as a result of their experiences were their needs. The needs were associated with the revision of the curriculum and teacher-trainings.

The teachers' most common suggestion was related to their enthusiasm for teaching with activities and time pressure on them. They expressed it as not having enough time to teach many subjects on the curriculum because of the intensity of the curriculum. They suggested removing this intensity by simplifying it. The response of P7 is an example of what these teachers suggested:

> We had a concern about being able to cover the curriculum at a certain time. Hence, we cannot allocate a long time for such lessons. I mean, the activity should be done quickly to pass the next subject. I wish for a simpler curriculum to teach mathematics to my students by using real-life connections, learning-by-doing, etc. So, the curriculum should be more simple.

P1 shared her views on the same subject by expressing that:

> There are many objectives in the curriculum. Yes, they [authority] made revisions on it, but it needs more. I think there should be a general framework for teaching concepts. Then we may implement such activities. They [authority] should reduce the intensity of the curriculum.

Some of the teachers expressed their need for the support of MoNE to acquaint themselves with these innovative teaching approaches. They suggested to MoNE to provide teacher training and open-sources that fulfill their needs. For example, P5 said:

> I think we [teachers] don't know these issues [innovative teaching approaches] well. We may have the potential to integrate them into our lessons effectively. But we don't know how we do. They [authority] should create awareness by organizing in-service training. Maybe, there is a book that consisted of similar activities. They should provide these aids to us.

Lastly, four teachers (P2, P4, P5, P13) suggested revising the curriculum to include sample activities as a guide for them. They thought including such activities in the curriculum could help all teachers to understand the structure of the tasks and shorten their time for researching.

4.7.3 Suggestions to Universities

Similar to some teachers' suggestions related to training and resources to MoNE, two of them advised universities, especially faculties of education. P11 elaborated her suggestion as given below:

> The faculties of education should research on these issues [innovative teaching approaches]. They should share their works, such as guidebooks, with us [teachers]. They may conduct a project related to these issues and train teachers in this context.

P4 shared her suggestions by mentioning the Internet as the way of knowledge sharing between universities and teachers by saying that:

> They should share their academic experiences and knowledge with us online. On the Internet, we can search for websites created by them and have an opportunity to develop ourselves as teachers. We may share our knowledge and experiences with our colleagues, and academics lead our teaching by giving feedback. This will be very beneficial for us to learn the theoretical part and for them to observe the practical part. They may create such sharing platforms, forums, portals, or websites, whatever it is.

To sum up, participant teachers asked education faculties to become a bridge between theoretical and practical sides of mathematics education in Turkey by sharing their extensive knowledge and experiences in teacher training activities and working with mathematics teachers to enhance their teaching methods.

CHAPTER 5

DISCUSSION AND RECOMMENDATIONS

In this chapter, the main conclusions of the study will be presented and discussed in detail with the purpose of investigating middle school mathematics teachers' views and experiences regarding innovative mathematics learning activities. Also, the conclusions will be presented in line with the discussion about previous studies. Then, implications and recommendations for further research will be addressed in the light of the conclusions and discussion about the findings of the current study.

5.1 Discussion of the Findings

In this part, the discussion of the findings will be presented in accordance with the research questions. In other words, teachers' perceptions of innovative mathematics learning activities, attributes of their innovative mathematics learning activities, emotions of teachers during innovative mathematics learning activities, effects of innovative mathematics learning activities on students, enablers of innovative mathematics learning activities, barriers of innovative mathematics learning activities, and suggestions about innovative mathematics learning activities will be discussed by taking previous related studies into account.

5.1.1 Teachers' Perceptions Regarding Innovative Mathematics Education

One finding of this study was that the participant teachers associated innovative mathematics education with non-traditional educational approaches. They established a connection between innovative mathematics education and 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. The participants stated that these categories make their mathematics lessons innovative. Normally, student-centered learning, connecting mathematics and real-life, using learning by doing strategy, active participation of students, activity-based learning, and interdisciplinary instruction should not be innovative approaches since the national middle school mathematics curriculum already addresses these approaches as what mathematics teachers do in their lessons (MoNE, 2018). According to participants, when they implemented these approaches, they perceived themselves as teaching mathematics lessons out of the ordinary. Although at the policy level these should be regular practices of the mathematics teachers, the participants see this kind of instruction as non-routine and innovative. This can be interpreted as the participants have more educational practices in line with the policy level suggestions even these practices are "innovative" and non-routine for them. So, policymakers should be careful about how national educational policies are perceived among teachers.

Although the participants did not explicitly mention any theoretical point of view, their descriptions can be interpreted to align with the constructivist and constructionist learning theories, which were recently promoted by the STEM learning approaches. It can also be argued that most of the participants' perceptions of innovative learning activities were in line with the recent rhetoric of STEM education. In addition, their descriptions of the activities they conduct in schools were parallel with the other approaches in mathematics education, such as mathematical modelling, project-based learning, problem-based learning, cooperative learning, or technology-integrated instruction. This finding can strongly indicate that the participants were aware and up-to-date on the relatively current theories in education and were willing to implement the ideas in these theories and approaches into their professional practices. It may be because most participants attended professional development seminars, in-service training programs organized by private schools or MoNE, and similar professional development activities.

Finally, as mentioned before, teachers' practices were commentated within the scope of STEM education and mathematical modelling because of the characteristics of their activities implemented. Their implementations were discussed in the light of STEM education and mathematical modelling.

5.1.2 Attributes of Implemented Innovative Mathematics Learning Activities

The participant teachers stated that they conduct innovative activities, most of which were STEM and modelling activities, mostly in the first three years of middle grades, and none of them practiced these types of activities with their 8th-graders. The primary reason for not implementing such activities in 8th-grade classrooms was the need for intense preparation for the national high school entrance exams. Since their activities are time-consuming and require significant teacher and student effort, implementing such activities might not have been preferred by teachers for preventing heavy workload for students. They might also predict adverse reactions of parents and school management if they will practice STEM and mathematical modelling activities with their 8th-graders. So, their preference to use innovative mathematics learning activities with younger middle school students can be interpreted as accepting the reality of national exams and avoiding the negative comments of students, parents, and school management regarding the pressure of the national exam. This is in accordance with the related studies in the literature and national exams perceived as a barrier for implementing STEM activities (Kurtuluş et al., 2017) and MEAs (Deniz & Akgün,2017; Yu & Chang, 2011) by teachers.

Teachers implemented their activities in their regular mathematics classes, elective courses, namely applications of mathematics and student clubs. The notable contexts of teachers' practices could be implementing during elective class hours and student clubs. The limited-time they mentioned and complained about during the interviews might be a reason for their choice. Since they were disposed to carry out both their regular mathematics teaching and innovative mathematics learning activities, they might need more time for their “extra” activities to sit the mathematics curriculum out. So the extra class hours provided as elective courses and student clubs might help them to be able to create time for the activities. The participant teachers in private schools had an opportunity to do the activities in student clubs. It can be concluded that middle school mathematics teachers have difficulty managing time and workload while implementing their STEM and mathematical modelling activities in available class hours. Many public school teachers have difficulty in implementing their activities in out-of-class contexts due to the limited facilities of their schools.

The content areas of innovative mathematics learning activities implemented by the teachers were numbers & operations and geometry & measurement. When the current middle school mathematics curriculum is examined, it is seen that the curriculum gives weight to these two content areas in terms of numbers of objectives and class hours compared to algebra and probability & statistics content areas, mostly in the first years of middle school (MoNE, 2018).

As mentioned before, teachers’ innovative mathematics learning activities can be considered in the scope of STEM education and mathematical modelling approaches because they preferred to establish a connection between mathematics concepts they aimed to cover and other disciplines such as science, technology, engineering, design, and social sciences. They gave importance to designing a model, using educational technology, raising social and environmental awareness, optimizing the criteria, combining with other science subjects, and encouraging students to work in groups. Such features of their learning activities consisted of theoretical aspects that define the characteristics of STEM education (Bybee, 2013) or mathematical modelling (Lesh & Doerr, 2013) activities. Although Bybee (2013) and Lesh and Doerr (2013) recommended implementing STEM and mathematical modelling activities by extending over a period of time in terms of more effective instruction, the participant teachers worked with these activities for approximately 4 class hours due to their limited time and workload discussed before and also later.

According to Harris et al. (2016), assessment and evaluation of interdisciplinary instruction should consist of both formative and summative techniques. Specifically, the assessment and evaluation carried out for STEM activities should have included multiple components related to core discipline, other interdisciplinary concepts, and skills due to the nature of STEM education (Sondergeld, 2014). Parallel to these, the participant teachers of the current study asserted that they give attention to be consistent with the non-traditional instructional approaches and use observation, discussion, questioning, performance tasks, peer rating, paper-and-pencil tests, and exit cards as means of assessment in their STEM and mathematical modelling activities.

Lastly, the teachers took or adapted their STEM and mathematical modelling activities from the Internet (social media and educational websites), professional development seminars they attended, and books & articles. Their information sources were in agreement with the teachers' beliefs about collaborating with other teachers and sharing with them to increase the viability and availability of activities related to STEM education (Asghar et al., 2012; Hanson & Carlson, 2005; Wang et al., 2011). This is also supported by the findings of the project related to STEM teachers' use of resources, especially digital resources, in their STEM instruction conducted by Hanson and Carlson (2005). According to their research, teachers stated that web resources and printed materials such as textbooks, books, and articles have an impact on their instruction planning, and they have benefitted from them to meet their educational needs in the instructional plan. Besides using in the planning phase of the instruction, these resources were used as a part of instruction during their lessons. Moreover, teachers remarked professional development seminars and colleagues as a resource of their instructional ideas and resource of finding out about new resources because of collaboration and communication in seminars and colleagues.

5.1.3 Teachers’ Emotional Engagement in Innovative Mathematics Learning Activities

The teachers expressed their emotions related to STEM and mathematical modelling activities, mostly in a positive manner. They felt satisfied, having fun, motivated, and excited due to their students’ positive reactions and emotions about their instruction. For instance, teachers believed that their innovative mathematics learning activities positively impacted students’ attitudes and skills in a diverse range. This is in agreement with the findings of the study conducted by Kim and her colleagues (2015). Their study about elementary pre-service teachers’ STEM engagement, learning, and teaching by using robotics in a teacher preparation course reported that the participants’ emotional engagement (e.g., enthusiasm, interest, enjoyment, happiness) in STEM-related robotics activities significantly promoted and they valued these activities as prospective elementary teachers. Participants teachers also had a negative emotional engagement with the activities as well. Namely, feeling tired or exhausted, related to their effort in the instruction period was a typical negative emotional response. Their exhaustion might be related to the time required for planning, implementing, and evaluating STEM and mathematical modelling activities while having other instructional responsibilities. The teachers’ heavy workload and the effort to conduct regular and activity-based classes both might be perceived as tiring by the participants.

5.1.4 Perceived Effects of Innovative Mathematics Learning Activities on Students

In the current study, perceived effects of the innovative mathematics learning activities on students were described as changes in attitudes and awareness, 21st-century skills, affective skills, psychomotor skills, and learning by the teachers based on their observations and experiences during implementations. These perceived effects will be discussed in the light of the findings explained in the previous chapter.

5.1.4.1 Perceived Effects on Attitudes and Awareness

The teachers argued that implementing innovative activities affected their students' awareness about career choices, social and environmental issues, and gender issues. Teachers attributed positive student outcomes to the STEM and modelling activities they conducted. Most of their activities were interdisciplinary in nature, which had the potential to broaden students' horizons in other disciplines beyond mathematics. The activities were also related to a diverse range of professions such as scientist, engineer, designer, and related to issues such as energy conservation, healthy nutrition, or a model design for the solution of a real-life problem. This structure of the activities that concern everyone regardless of age, gender, or educational background might eliminate students' prejudices about gender issues and minimize their occupational gender stereotypes. This is in agreement with the findings of the study conducted by El-Deghaidy and Mansour (2015). The findings of their study about identifying Saudi Arabian science teachers' perceptions on STEM education demonstrated that teachers consider that teaching via STEM activities and connecting science concepts with real-life situations inspire their students to choose future occupations in STEM fields. According to teachers, the interdisciplinary nature of STEM activities enables students to understand the use of technology and the relationship between real-life and scientific concepts. So, these can attract students' interest and foster their motivation in studying science and take careers in STEM fields. Also, Breiner et al. (2012) reported that STEM activities could be useful for giving students the opportunity to explore their interests, potentials, and abilities. This leads students to choose more suitable occupations for them, especially STEM-related occupations. Further to that, Christensen & Knezek (2017) reported in their research with more than 800 middle school students that students who have STEM education experiences tend to prefer STEM-related occupations compared to the students who have no similar experiences, and female students have more positive reactions to the activities and STEM-related occupations than male students.

Many of the teachers observed that students' social and environmental awareness has increased after their instruction. Similar to the observations of the current study, Özçakır-Sümen and Çalışıcı (2016) argued that STEM activities are useful in creating social and environmental awareness in their study about STEM education practices in environmental literacy course with prospective teachers. Likewise, Helvacı and Helvacı (2019) inferred that STEM activities positively affect students' environmental awareness in their study about environmental education with 6th-grade students.

According to the participant teachers' perceptions and observations during and after STEM and mathematical modelling activities, their students' effort, participation, and perseverance had changed positively. In other words, the students began to demonstrate increasing effort and persistence to learn mathematics and to participate in mathematics lessons more and ambitiously, as reported in the study of Lesseig et al. (2016). Since students' motivation, interest, and academic achievement have enhanced, thanks to STEM and mathematical modelling activities according to teachers' perceptions, the students' perceptions that mathematics lessons are difficult and tedious might be declined. Besides, unlike traditional mathematics instruction, the student-centered nature of these activities might play an essential role in overcoming students' negative perceptions and then their active participation and hard effort to learn mathematics. The positive effects of innovative mathematics learning activities on students' engagement are in accordance with the study carried out by Lee et al. (2019). The study was about investigating the impact of STEM project-based learning and non-STEM project-based learning lessons on 9th-graders' affective mathematics engagement, and findings of the study revealed that students in lessons using STEM project-based learning approach demonstrate more positive mathematical attitude, emotion, self-acknowledgment, and value than students in lessons using non-STEM project-based learning approach. So, it is concluded that STEM project-based learning activities foster students' affective mathematics engagement.

5.1.4.2 Perceived Effects on 21st-Century Skills

The participant teachers argued that implementing innovative mathematics learning activities affected students' 21st-century skills positively. During the activities, teachers were making their students use several skills. For instance, researching a topic, communicating, and collaborating were some of the skills utilized during the activities. Since STEM and modelling activities require finding a solution to a real-life problem by designing a model, students might need to think of all possible solution strategies and overcome difficulties encountered in the design process by redesigning their solutions. In this way, teachers can witness students' intense use of a diverse range of 21st-century skills, including creativity, critical thinking, and problem-solving skills. These findings are consistent with the study conducted by Bozkurt-Altan and Ercan (2016) to investigate science teachers' perceptions and competencies and the effects of professional development seminars about STEM education on their perceptions and competencies. The views of participant science teachers supported the views of participant mathematics teachers of the current study by saying positive effects of STEM activities on students' 21st-century skills. They perceived STEM activities as an enabler of developing students' problem-solving, research, creativity, and critical thinking skills. Also, the research showed that professional development seminars were effective to enhance teachers' perceptions, conceptions, views, and knowledge about STEM education. Further to that, the other studies in the literature that based on the implementation rather than perception and views present 21st-century skills development originated from the implementation of STEM and modelling activities in lessons (Özçelik & Akgündüz, 2018; Becker & Park 2011; Güder & Gürbüz, 2018; Kertil & Gürel, 2016; Lesseig et al., 2016; Şahin et al., 2014; Zawojewski et al., 2003).

5.1.4.3 Perceived Effects on Affective Skills

Another point teachers made about the effects of innovative activities on students was related to the affective dimension. They argued that getting involved in the activities improved their students' motivation, attention, self-confidence, and a sense of achievement. It can be concluded from the participant teachers' views and experiences that the non-routine structure of the STEM and mathematical modelling activities might attract students' attention more to the lesson than conventional classroom teaching. Students' increased attention might lead them to be motivated to learn concepts covered in the activity and participate in the lesson more than regular mathematics lessons, leading to an increased sense of achievement. In these types of activities, teachers have more chances to observe their students in productive work, discussions, and group works. When teachers see their students' enthusiastic participation in-class activities, they might develop a perception that students can solve problems and design models in a self-confident manner. Similar effect of mathematical modelling activities on students' affective skills founded by Akgün et al. (2013). In their phenomenological study, the participant middle school mathematics teachers stated that they prefer to use mathematical modelling activities since their students' attitudes towards mathematics lessons are affected positively. Teachers attributed students' positive attitudes towards mathematics lessons to students' increased awareness of the strong relationship between mathematics and real-life thanks to mathematical modelling activities. Moreover, there are studies that found the positive effects of STEM and mathematical modelling activities on students' affective domain of learning (Bruce-Davis et al., 2014; Hernandez-Martinez & Vos, 2018; Lesseig et al., 2016) in the literature.

5.1.4.4 Perceived Effects on Learning

Teachers also argued that innovative activities improved students' learning, referring to meaningful learning and higher academic achievement. Their emphasis on meaningful learning may be due to the nature of the activities, which involved solving real-life problems and connecting mathematics to other disciplines. Observing their students on such tasks that focus on learning-by-doing and apply mathematical knowledge into real tasks might lead teachers to conclude that their students are learning in a meaningful way. The finding related to the participant teachers' perception on positive effects of innovative mathematics activities on student learning is in accordance with the study related to examining STEAM teachers' perceptions and practices conducted by Park et al. (2016). They found that most of the teachers believe the value of STEM education in terms of its potential positive effect on student learning since it impacts their thinking skills and attitudes towards lessons affirmatively. In the same vein, integrating mathematical modelling into lessons was perceived as one of the most effective factors in providing meaningful and permanent learning to students and increasing their mathematics achievement by middle school mathematics teachers (Akgün et al., 2013). So, it can be claimed that teachers believe positive effects on their students' learning outcomes and these type of activities are useful in mastering STEM education (Asghar et al., 2012; Bolatlı & Korucu, 2018; Özçelik & Akgündüz, 2018; Wang et al. 2011; Yıldırım, 2018) and mathematical modelling activities (Güder & Gürbüz, 2018).

5.1.4.5 Perceived Effects on Psychomotor Skills

According to the teachers implementing innovative mathematics learning activities affected students' psychomotor skills and lead students to develop them. The reason behind this might be the characteristics of the STEM and modelling activities, as the teachers mentioned. Since these types of activities include drawing their prototypes, measuring areas or angles, cutting papers or cardboards, gluing materials together in the design stage, etc., they provide an environment for the students to increase their psychomotor skills, especially for younger ones.

5.1.5 Enablers of Providing Innovative Mathematics Learning Activities

In the current study, the teachers stated that some enablers lead them to increase the quality of their lessons in which they implemented innovative mathematics learning activities. The teachers identified their supportive factors by associating the factors with themselves and 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 related to the contexts of the activities. The enablers in innovative mathematics learning activities were described as (1) collaborating with colleagues, (2) receiving support from school management, (3) receiving positive feedback from parents, (4) thinking about students' possible questions, (5) receiving positive reactions from students, and (6) talking with an expert from a different profession. These enablers can be interpreted as receiving support from others (namely colleagues, school management, parents, students, and experts) more generally. So, the teachers do not want to be alone through the innovative mathematics learning activities, and they need support and collaboration during the process.

Since the STEM activities and mathematical modelling activities require the integration of the disciplines and presentation of the integrated activities to the students for preparing them for the 21st-century by equipping them with skills (Bybee, 2013), it was inevitable for the participant mathematics teachers to collaborate with their colleagues from other disciplines such as science and technology. Moreover, many teachers in the study expressed that they mostly collaborate with other mathematics teachers as well as science and technology teachers to enhance the quality of their lessons by increasing the plausibility of the activities and by drawing them toward the real-life. In parallel with this finding, Herro and Quigley (2017) remarked that collaborative working with colleagues is critical for guiding teachers to think beyond and maximize their knowledge outside of their discipline in their study about perceptions and practices of middle school mathematics and science teachers on STEM education. Collaboration with colleagues in planning, implementing, and evaluating processes of the lessons might conduce to practice them effectively and strengthen student learning. Also, teachers might have the advantage of minimizing their current or future challenges in lesson planning by discussing with other teachers and enabling them to expertise more in other disciplines. To be able to build a collaboration of colleagues, school management should support teachers by providing a working environment for them (Stohlman et al., 2012; McMullin & Reeve, 2014) and eliminating teachers' concerns about their schedules, in other words making time for implementation of the activities (Herro & Quigley 2017).

In a similar vein, the findings of the current study reported that receiving support from school management encourages middle school mathematics teachers to develop and implement innovative mathematics learning activities. The participant teachers experienced their school management's moral and material support and similar educational perspectives to maximize student learning as enablers of providing innovative mathematics learning activities. As stated in the study related to standards of the process of creating, implementing, and assessment of project-based learning by bridging the frameworks and their applications in the classrooms conducted by Larmer et al. (2015), the alignment of the school management's vision, mission, and values and their teachers' is key to success in project-based learning activities such as STEM and mathematical modelling activities. It can be concluded that common educational perspectives of the school management and teachers have a significant role in being able to implement STEM and modelling activities. So, their shared values, concerns, and views might lead them to cooperate to enhance and diversify mathematics lessons. Similar to collaborating with colleagues, talking with an expert from different professions such as electrical and electrics engineers, food engineers, environmental engineers, and architects facilitated the participant teachers to learn technological tools, diversify contexts of the activities and make more precise relationships between mathematics and real-life.

Another enabler of providing innovative mathematics learning activities was founded as receiving positive feedback and reactions from parents and students about the process and outcomes of the activities. Teachers observed that as students become aware of the positive effects (before-mentioned and discussed in section 5.1.4) on their awareness, skills, and learning, they are disposed to participate more in lessons, take responsibility for their own learning, and mastering more in mathematics lessons. These were interpreted by teachers as a driving force for students' motivation and interest in mathematics lessons, thanks to STEM and mathematical modelling activities. With the help of the increased interest and motivation, their students tended to share their constructive feedback or outcome on the instruction, likewise the studies of Herro and Quigley (2017) and Lesseig et al. (2016). Moreover, teachers mentioned that parents' perception of the change in their children's attitudes towards mathematics originated from innovative instruction. According to their experiences, parents were pleased to observe positive changes in students' motivation and interest, and they gave positive feedback about this to the teachers. Depending on receiving positive feedback from students and parents, teachers believed that it contributes to their motivation to implement similar activities. They thought that they feel satisfied and consider their activities as more valuable since their instruction serves the purpose with such evidence. Teachers also had an improved sense of teaching efficacy affected positively by affirmative feedback and reactions.

The last enabler mentioned by teachers that support them in the process of innovative mathematics learning activities was thinking about students' possible questions. Teachers stated that since these types of activities are unfamiliar for their students and integrate mathematics into other disciplines, their students have many questions in their minds to be able to design a model or find a solution. Therefore, trying to detect students' possible questions, misconceptions, difficulties, or reactions enables teachers to implement more well-designed and more effective STEM and mathematical modelling activities. Blum (2011) addressed this finding of the current study by mentioning the role of a mathematics teacher in a mathematical modelling activity as predicting and understanding the students' difficulties during the mathematical modelling process. Similarly, Carlson et al. (2016) indicated the teachers' role in the mathematical modelling process by stating anticipating the students' possible reactions and solutions as the first step of planning and developing mathematical modelling activities.

5.1.6 Barriers in the Process of Innovative Mathematics Learning Activities

In the current study, the teachers stated that they encountered some barriers that damaged the quality of their lessons implementing innovative mathematics learning activities. The barriers in the process of innovative mathematics learning activities were described as difficulties encountered in the preparation, implementation, and evaluation stages of innovative mathematics learning activities. In the activity process, teachers had barriers in terms of time, students' learning habits, classroom learning culture, work environment, and preparation. These barriers will be discussed in the light of the findings explained in the previous chapter.

5.1.6.1 Barriers related to Time

Time was described as a barrier in terms of having limited implementation time for innovative mathematics learning activities in concern with covering the middle school mathematics curriculum and preparing students for the national exams. Innovative mathematics learning activities, especially STEM and mathematical modelling approaches, include connections to other disciplines such as science, technology, and engineering, presented in an integrated manner to students. This integrated structure of the activities necessitates students' time to solve real-life problems using their mathematical knowledge and designing a model as a solution after their research process. Since teachers should cover the objectives in the mathematics curriculum and prepare their students for national exams, implementation time for the activities is significantly limited. Therefore, time is a barrier for teachers who want to implement innovative mathematics learning activities. This finding is consistent with similar studies that concluded time as a concern of teachers while planning and implementing STEM activities (Goodpaster, Adedokun & Weaver, 2012; Park et al., 2016) and mathematical modelling (Akgün et al., 2013) in their lessons Time pressure originated from national high school and university entrance exams prompts mathematics teachers to resist implementing model eliciting activities in their classes (Yu & Chang, 2011). From a different viewpoint, time may be a barrier for teachers since they need to find more time to plan and prepare their activities (Hsu et al., 2011; Park et al., 2016).

5.1.6.2 Barriers related to Students' Learning Habits and Classroom Learning Culture

One category of barriers that the teachers mentioned were students' learning habits and classroom learning culture, because of students' traditional learning background, such as teacher-centered instruction and working individually. Students develop habits based on the norms of teacher-centered classrooms, which makes it difficult for them to adapt to a learning-by-doing environment. This results in several difficulties for teachers in classroom management. The students tended to ask every step in the innovative mathematics learning activities to their teachers because of the need for getting approval. This finding is supported by the results of the studies related to mathematical modelling activities conducted by Moore and her colleagues (2015) and Zawojewski et al. (2003). For instance, Moore et al. (2015) conducted an MEA called Pelican Colonies with 6th-grade students to develop their understanding of the concept of area. According to their findings, students needed to get feedback from teachers during the MEA since they familiar with traditional lessons in which they don't need to get feedback or approval from teachers to work on mathematical concepts. Similarly, Zawojewski et al. (2003) emphasized students' tendency to get feedback on their way of thinking, solution, or model during MEAs as a result of their learning habits included limited implementation of mathematical modelling activities. Also, they stated that teachers are more willing to implement MEAs when they feel that their students demonstrate their effort to adapt their new role in the learning process during MEAs, on the contrary to being disposed to obtain feedback from them in every step of the MEAs. Besides, being familiar with teacher-centered instruction pointed out a barrier to implementing STEM education practices by Lesseig et al. (2016), and they emphasized the need for the fundamental changeover from teacher-centered instruction to student-centered instruction to overcome this barrier by changing students' learning habits in a non-traditional manner.

Although students were responsible for their own learning by taking part as active learners, they misunderstood their active role in the learning process by seeing mathematics lessons as playing time. Also, the students tended to work individually. Their habit of working individually and resistance to work in groups indicated as a barrier to implementing mathematical modelling activities, although teachers pointed out the requirement of group-working at the beginning of their activities to students (Eraslan &Kant, 2015) and to prospective mathematics teachers (Eraslan, 2012). Other students, who did not prefer working individually, tended to work with their close friends, mostly at the same level of success. This may be due to the students' lack of experience in student-centered instruction and teamwork since regular mathematics education practices in Turkish schools are mainly direct instruction, and teachers are the information sources. In addition, preparation for high-stakes exams makes students value solving mathematical questions as quickly as possible, leading them to have difficulty adapting to the pace of student-centered activities. Most of the mathematical problems they see in the textbook and the tests are well defined, while the problems in the STEM or modelling activities tend to be ill-defined. This leads to difficulties in understanding and formulating the problem. These barriers related to students' learning habits and classroom learning culture are complemented by the research carried out to investigate 5th-grade students' behaviors emerged and changed and barriers encountered during MEAs by Dedebaş (2017). The research revealed that students tend to work alone at the beginning of implementation and have difficulties in understanding the real-life problems given MEAs because of the ill-defined structure of the problems. Due to their previous experiences and learning habits, they needed to explain problems in MEAs and obtain approval from the teacher at their solution process. However, it is founded that students' learning habits can change as being familiar with student-centered instruction and their active role after sustained implementation of MEAs.

Due to students' lack of familiarity with student-centered teaching and group-work, classroom management was another barrier. Teachers' role in grouping students and leading their group-work by eliminating their tendency to talk with each other and make noise perceived as making classroom management difficult. Difficulty in classroom management might have many reasons, such as students' distraction due to using materials, the activity content that includes connections to real-life or other content areas, and the activities that take more than one session. Dedebaş (2017) pointed out that students need to get approval and explanation during MEAs for better understanding and have difficulties related to time management and understanding the issue. These can be identified as barriers related to classroom management since teachers need to work for leading students by explaining concepts and encouraging for group-work.

5.1.6.3 Barriers related to the Work Environment

The work environment was identified as a category of barriers. In this category, the teachers' heavy workload, lack of equipment needed to implement the activities, and destructive criticism of their colleagues about their activities or teaching style were the main barriers to implementing the innovative activities. Since the planning, implementation, and evaluation processes of the activities require more time than teachers' other regular class teaching activities, the teachers complained about their increased workload as an obstacle to their innovative mathematics learning activities.

It was founded that innovative mathematics learning activities include mathematics curriculum objectives and other objectives related to science, technology, and engineering. This interdisciplinary nature of the activities requires that students design a model for real-life problems using their knowledge about these disciplines. The research and design processes of the models may require the use of various materials and technological tools, as well as suitable places for students to work on the activities. Although some of the activities could be implemented with more accessible materials, inadequacy or insufficiency of materials is a barrier to implement STEM and mathematical modelling activities. The barrier related to material supply founded in the current study is consistent with Morrison's (2006) study. She suggested the attributes of STEM classrooms as equipping with specialized hardware and software related to STEM education, having a range of different educational materials, and having classroom equipment suitable for students by emphasizing that their absence will be a barrier to the desired implementation of STEM education. The barrier related to equipment is emphasized in one of the first and extensive reports about STEM education in Turkey conducted by MoNE, and it is stated that material barriers should be overcome by providing equality in opportunity (MoNE, 2016).

The last barrier to implementing innovative mathematics learning activities related to the work environment was the destructive criticism of colleagues. Teachers suffered from their opposing views on the activities and their colleagues' non-progressive teaching styles because of their appropriation of being a traditional mathematics teacher. This may have resulted from differences in their colleagues' and their perspectives and limited communication between them. Although teachers give importance to cooperating with other teachers for better instruction, they also suffer from limited communication between colleagues (Al-Salami, Makela & de Miranda, 2017). Since most of the participants of the study were regarded as new in the teaching profession according to others and they were willing to improve themselves as teachers by participating in seminars or continuing graduate education, their innovative teaching styles might be conflicted with their colleagues' traditional teaching styles. This conflict between them might cause their colleagues to criticize their innovative mathematics learning activities negatively, and that might create an obstacle to the implementations of the teachers who are demoralized and demotivated by these destructive comments. These inferences are overlapped with the findings of the study conducted by Çevik, Danıştay and Yağcı (2017). They explained that teachers' awareness of STEM education is affected negatively when their professional seniority increases and educational background decreases. In brief, they founded that young teachers and teachers who have graduate education tended to implement STEM activities more in their lessons thanks to their positive STEM awareness.

5.1.6.4 Barriers related to Activity Preparation

The activity preparation process was identified as another category of barriers. This category includes teachers' difficulties in integrating mathematics objectives and other disciplines, lack of knowledge and experiences about STEM and mathematical modelling activities, and difficulty in simplifying complex concepts for their students. When the experiences and the views of the teachers were examined, it can be concluded that difficulty in activity preparation has its source mainly from the teachers' insufficient subject matter knowledge regarding STEM and mathematical modelling contents and their related few-in-number implementations due to barriers before-mentioned. So, their lack of knowledge and experiences about STEM and mathematical modelling activities can cause difficulty in making connections between mathematics and other subjects and revising their activities according to their students' level. The study of Lederman and Lederman (2013) argued that science and mathematics teachers' have difficulties in integrating science and mathematics concepts and in establishing relationships with technology and engineering. According to their findings, integrating science and mathematics concepts is easier for science teachers than mathematics teachers since mathematics teacher education programs are less interdisciplinary than science teacher education programs. The findings of the current study are in agreement with the related studies included teachers' concerns about integration (Asghar et al., 2012; Herro & Quigley, 2017; Lesseig et al., 2016; Wang et al., 2011). For instance, Wang et al. (2011)

indicated that although teachers have knowledge about the requirement of integration during their STEM-related instruction, they don’t have knowledge about how they achieve this goal because of their limited knowledge about other disciplines. According to the findings of their study, teachers mostly had difficulties in integrating technology into their lessons since they have a lack of knowledge and experience on how they use technology in their classroom practices and lack of easy access to technological tools. Similarly, the teachers thought they needed to know and experience how their curriculum should be implemented and integrated with other curriculums during their pre-service or in-service training programs (Nadelson and Seifert, 2013).

5.1.7 Suggestions About Innovative Mathematics Learning Activities

The participant middle school mathematics teachers were asked to give recommendations to relevant stakeholders for better innovative mathematics education by taking both supporting factors and difficulties they experienced into consideration. Their suggestions were for teachers who implement STEM and mathematical modelling activities, MoNE, and universities. They suggested that teachers need to research to be up-to-date, know students’ characteristics and interests, observe and guide students, be persistent in implementing, start with the well-known, similar activities, get opinions of others, and learn a foreign language. They suggested simplifying the mathematics curriculum, putting sample activities in the curriculum, and providing training and resources for teachers to MoNE and universities. In the literature, some studies supported the teachers’ suggestions on enhancing teacher knowledge about STEM and mathematical modelling activities to maximize students’ outcomes accordingly. For instance, Zawojewski et al. (2003) pointed out that teachers should implement mathematical modelling activities by considering their students’ backgrounds. Similar to the training and resource need and suggestions of participant mathematics teachers, Lehman et al. (2014) reported that science teachers require STEM integration knowledge and practices, and they think that universities should meet their requirements by collaborating with them.

5.2 Implications of the Study

In this part, the implications based on the before-mentioned findings will be presented in accordance with the purpose of investigating middle school mathematics teachers’ views, experiences, and suggestions on STEM and mathematical modelling activities. Since the integration of STEM and mathematical modelling activities into mathematics lessons is relatively new, it is considered that there is a necessity for informing educational stakeholders about the integration processes of these types of activities. The current study has some implications for teachers, school management, the MoNE, and teacher educators.

The findings of the study revealed that teachers have positive emotional engagements about innovative mathematics learning activities. Their satisfaction, motivation, and excitement take their sources from the positive effects of their STEM and mathematical modelling activities on students’ skills, learning, and achievement according to their perceptions based on their practices compared to their regular mathematics instruction. When they feel satisfied, motivated, and excited, they tend to implement similar activities to maximize student motivation and learning by diversifying their lessons. Therefore, mathematics teachers can plan their lessons by incorporating STEM and mathematical modelling activities due to participant teachers’ perceived emotions during their lessons implemented these types of activities.

The current study showed that participant teachers observed that their innovative mathematics learning activities positively affect their students’ attitudes, awareness, 21st-century skills, motivation, participation, and learning. This leads them to have higher teaching efficacy beliefs since they consider that their activities maximize student learning, foster their abilities, and be useful for raising well-educated 21st-century individuals.

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 modelling activities ambitiously. Correspondingly, teachers should be encouraged to implement their activities by creating a collaborative working environment and by taking moral and material supply by the school management at the school level and by the MoNE at the national level. So, in-service teacher training programs can be conducted to increase communication and collaboration between mathematics teachers and others. In addition, teachers who want to implement STEM and mathematical modelling activities in their mathematics instruction should consider the importance of the innovative mathematics learning activities and their positive reflections and effects on students and their parents. So, they should create an environment where their students and their parents can share their opinions about their teaching style.

On the other hand, the current study put forward that teachers get into several difficulties and enablers 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 modelling activities. The MoNE and researchers can develop strategies to overcome these difficulties for better mathematics education. For example, the MoNE should develop policies about teachers' workload, mathematics class hours, and mathematics curriculum by revising them in accordance with STEM and mathematical modelling activities. The schools should be equipped with materials needed to implement STEM and mathematical modelling activities. These types of activities should be integrated into the primary school curriculum to make students more familiar with STEM and mathematical modelling in their early grades and middle school curriculum. Another revision may be in teacher education programs at universities. Teacher educators should makeover their curriculum to provide STEM and mathematical modelling teacher competencies to the prospective teachers. By changing teacher education programs, teacher educators may overcome the lack-of-knowledge-barrier by equipping prospective teachers with the new educational approaches and enhancing teacher quality. In policy of complying teachers with innovative educational trends, in-service teachers should be incorporated into the period of change as well as pre-service teachers. Thanks to including in-service teachers in the educational change policies, they may become more knowledgeable and experienced in STEM and mathematical modelling activities. The MoNE and teacher educators should coordinate and collaborate while in-service teacher training programs to teach characteristics of the STEM and mathematical modelling activities to the current teachers. Also, the collaboration of the MoNE and universities may establish a bridge between the theoretical and practical sides of mathematics education in Turkey. Therefore, in order to help teachers and improve themselves, the revision of the mathematics curriculum may include sample activities and guides related to STEM and mathematical modelling.

The last implication of the current study is related to teachers' suggestions based on what they got from their experiences about STEM and mathematical modelling activities. These suggestions for teachers to implement innovative mathematics learning activities more effectively can be summarized as being up-to-date, researching about new educational approaches and technologies, knowing students' backgrounds, leading students during implementation, trying to implement these type of activities consistently, beginning with simple and popular activities, and collaborating with colleagues. Teachers who want to implement STEM and mathematical modelling activities should consider these suggestions while planning and implementing the activities in their lessons to enhance the quality of their lessons and eliminate the possible barriers. Besides, educational policymakers in universities and the Ministry of National Education can use these suggestions emerging from the teachers' experiences to determine and analyze their needs and design new professional development programs.

5.3 Recommendations for Further Studies

In this part, some recommendations in the light of the before-mentioned findings will be given for further studies. Firstly, similar studies about investigating teachers' views and experiences about STEM education and mathematical modelling can be conducted by increasing the number of participants and diversifying their professions since the current study was conducted with a limited number of 13 middle school mathematics teachers. So, further research about teachers' practices with STEM and mathematical modelling activities can be carried out with science, technology, and primary school teachers from different levels such as primary school and high school.

Secondly, the data collection tools can be enhanced in further studies. The data collection tool of the current study was interviews. Conducting similar studies by using other mixed designs involving both qualitative and quantitative data collection tools can be suggested to obtain more content-rich data.

Thirdly, a longitudinal study can be conducted to detect the changes in teachers' views and experiences and to understand the reasons behind the change. For example, novice teachers or teachers who implemented STEM and mathematical modelling activities for the first time can be participants of the longitudinal studies to be able to investigate the change in their preferences, views, enablers, and barriers related to STEM and mathematical modelling activities over time. This can enable researchers to extend their theoretical and practical knowledge about innovative mathematics education.

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APPENDICES

A. INTERVIEW PROTOCOL

Görüşme Soruları

Tanıtıcı/Kişisel Bilgiler

- Mezun olduğunuz fakülte türü ve branş nedir? Şu andaki branşınız nedir?
- Öğrenim dereceniz nedir?
- Kaç yıldır öğretmenlik yapıyorsunuz?
- Bu okulda kaç yıldır çalışıyorsunuz?
- Önceden ve/veya şu anda ders verdiğiniz sınıf düzeyleri nelerdir?

Bölüm 1 (Öğretmenlik Mesleği ile İlgili Genel Bilgiler)

1. Öğretmenlik mesleğini seçmeye nasıl karar verdiniz?
2. Öğretmenlik kariyerinizi etkileyen ve sizi bugünkü "… Öğretmen" olarak şekillendiren değerleriniz ve deneyimleriniz nelerdir?
3. Öğretim yöntemleriniz kariyeriniz boyunca nasıl değişti/gelişti?

Bölüm 2 (Yenilikçi Eğitim-Öğretim Uygulamaları ile İlgili Bilgiler)

4. "Yenilikçi eğitim-öğretim uygulamaları" deyince ne anlıyorsunuz?
5. Siz bu kapsamda neler yapıyorsunuz?
6. Öğrencileriniz için geliştirdiğiniz gerçek hayat uygulamalarını içeren, yenilikçi matematik eğitim-öğretim faaliyetinizden bahseder misiniz?
7. Bu faaliyetinizin sizin için önemi nedir?
8. Sizi bu faaliyeti gerçekleştirmeye iten faktörler nelerdi?
9. Bu faaliyetiniz boyunca kendinizi öğretmen olarak nasıl hissettiniz?
10. Bu faaliyetinizin hazırlık aşamasında diğer eğitim paydaşları (öğrenci, meslektaş, veli) sürece ne şekilde dahil oldu?

11. Bu faaliyetinizin uygulama aşamasında diğer eğitim paydaşları (öğrenci, meslektaş, veli) sürece ne şekilde dahil oldu?

12. Bu faaliyetinizin değerlendirme aşamasında diğer eğitim paydaşları (öğrenci, meslektaş, veli) sürece ne şekilde dahil oldu?

13. Bu faaliyetinizde karşılaştığınız güçlükler nelerdir?

14. Karşılaştığınız güçlükleri nasıl aştınız?

Bölüm 3 (Değerlendirme ve Öneriler)

15. Bu tip faaliyetler yapan öğretmenleri destekleyen faktörler nelerdir?

16. Bu tip faaliyetler yapan öğretmenleri engelleyen faktörler nelerdir?

17. Dersinizin öğretim programını, bu tipteki eğitim-öğretim faaliyetleri bakımından nasıl değerlendiriyorsunuz?

18. Dersinizin öğretim programını, bu tipteki eğitim-öğretim faaliyetlerine uygunluk bakımından nasıl değerlendiriyorsunuz?

19. Bu tip eğitim-öğretim faaliyetlerini sınıfında uygulamak isteyen bir öğretmene tavsiyeleriniz nelerdir?

B. CONSENT FORM

ARAŞTIRMAYA GÖNÜLLÜ KATILIM FORMU

Bu araştırma, ODTÜ Matematik ve Fen Bilimleri Eğitimi Bölümü Yüksek Lisans öğrencisi Elçin Erbasan tarafından Prof. Dr. Erdinç Çakıroğlu danışmanlığındaki yüksek lisans tezi kapsamında yürütülmektedir. Bu form sizi araştırma koşulları hakkında bilgilendirmek için hazırlanmıştır.

Çalışmanın Amacı Nedir?

Araştırmanın amacı, Türkiye'de yenilikçi matematik eğitimi etkinliklerini uygulayan ve/veya uygulamaya çalışan ortaokul matematik öğretmenlerinin yenilikçi matematik etkinlikleri hakkındaki görüşlerine, bunlar ile ilgili engeller, çözümler ve önerilerine dair bilgi toplamaktır.

Bize Nasıl Yardımcı Olmanızı İsteyeceğiz?

Araştırmaya katılmayı kabul ederseniz, sizden beklenen, Görüşme Protokolünde yer alan ve araştırmacının size yönelttiği sorulara detaylı, anlaşılır ve samimi cevaplar vermenizdir. Yaklaşık olarak bir saat sürmesi beklenen bu görüşmede vereceğiniz cevaplar, daha sonra analiz edilmek üzere, ses kaydı ile kayıt altına alınacaktır.

Sizden Topladığımız Bilgileri Nasıl Kullanacağız?

Araştırmaya katılımınız tamamen gönüllülük temelinde olmalıdır. Cevaplarınız tamamıyla gizli tutulacak ve sadece araştırmacılar tarafından değerlendirilecektir. Katılımcılardan elde edilecek bilgiler toplu halde değerlendirilecek ve bilimsel yayımlarda kullanılacaktır.

Katılımınızla ilgili bilmeniz gerekenler:

Çalışma, günlük hayatta karşılaşılması olası risklerin ötesinde herhangi bir risk ve kişisel rahatsızlık verecek sorular içermemektedir. Ancak, görüşme sırasında sorulardan ya da herhangi başka bir nedenden ötürü kendinizi rahatsız hissederseniz görüşmeyi yarıda bırakıp çıkmakta serbestsiniz. Böyle bir durumda görüşmeyi uygulayan görüşmeyi tamamlayamayacağınızı söylemek yeterli olacaktır.

Araştırmayla ilgili daha fazla bilgi almak isterseniz:

Görüşme sonunda, bu çalışmayla ilgili sorularınız cevaplanacaktır. Bu çalışmaya katıldığınız için şimdiden teşekkür ederiz. Çalışma hakkında daha fazla bilgi almak için Matematik ve Fen Bilimleri Eğitimi Bölümü yüksek lisans öğrencisi Elçin Erbasan (erbasan@metu.edu.tr) ya da öğretim üyesi Prof. Dr. Erdinç Çakıroğlu (erdinc@metu.edu.tr) ile iletişim kurabilirsiniz.

Yukarıdaki bilgileri okudum ve bu çalışmaya tamamen gönüllü olarak katılıyorum.

(Formu doldurup imzaladıktan sonra araştırmacıya geri veriniz)

Ad Soyad Tarih İmza

C. METU HUMAN SUBJECTS ETHICS COMMITTEE APPROVAL

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Konu : Değerlendirme Sonucu

Gönderen: ODTÜ İnsan Araştırmaları Etik Kurulu (İAEK)

İlgi : İnsan Araştırmaları Etik Kurulu Başvurusu

Sayın Prof.Dr. Erdinç ÇAKIROĞLU

***Danışmanlığını yaptığınız Elçin ERBASAN'ın "Ortaokul Matematik Öğretmenlerinin Yenilikçi Matematik Etkinlikleri ile ilgili Görüşlerinin İncelenmesi*"** başlıklı araştırması İnsan Araştırmaları Etik Kurulu tarafından uygun görülmüş ve **2018-EGT-192** protokol numarası ile onaylanmıştır.

Saygılarımızla bilgilerinize sunarız.

Prof. Dr. Mine MISIRLISOY
İAEK Başkanı