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Marmara University
The Graduate School of Educational Sciences
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ELEMENTARY SCHOOL TEACHERS' DEVELOPING PEDAGOGICAL CONTENT KNOWLEDGE AND BELIEFS ABOUT INTEGRATED STEM EDUCATION THROUGH A PROFESSIONAL DEVELOPMENT KNOWLEDGE

Esra CERAN

(Doctoral thesis)

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Supervisors
Prof. Dr. M. Cihangir Dogan
Dr. Mahmut Kertil

Istanbul, 2021

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Marmara Üniversitesi
Eğitim Bilimleri Enstitüsü
Temel Eğitim Ana Bilim Dalı
Sınıf Öğretmenliği Bilim Dalı

SINIF ÖĞRETMENLERİNİN BİR MESLEKİ GELİŞİM PROGRAMI KAPSAMINDA STEM EĞİTİMİNE İLİŞKİN PEDAGOJİK ALAN BİLGİLERİ VE İNANÇLARININ GELİŞİMİ

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(Doktora Tezi)

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İstanbul, 2021

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- I have cited all the works that I have used in my work,
- I declare that I have not made any changes in the data and results I have obtained, otherwise I declare that I accept all the loss of rights that may arise against me.

…./…./….

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DEDICATION

This dissertation is dedicated to all female students at multiple intersections of discrimination throughout their education. I sincerely hope one day you will be valued, supported, and have equity to unlock your full potential.

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ABSTRACT

The aim of this study is to examine the pedagogical content knowledge, pedagogical beliefs, and in-class practices of elementary teachers in the process of attending a professional development course and performing integrated STEM (Science, Technology, Engineering, Mathematics) education in their classrooms. In this research, case study was used as a research design. Three teachers who worked as elementary teachers in a public school in Istanbul during the semester break and spring semester of the 2018-2019 academic year participated in this research. A professional development course was developed and applied by researcher during the semester, STEM modules were developed and implemented by the teachers in the following period. Reflections were made on the practices and the researcher's support continued. Data were collected through interviews, observations, document analysis (teachers' science and mathematics autobiographies, classroom activities, visuals, assessment-evaluation tools), audio recordings and video recordings. Data analysis was performed with comparative analysis techniques.

The findings of the study revealed that teachers' pedagogical beliefs and pedagogical content knowledge about STEM education changed and improved with the professional development course. As a result, teachers' practices have also changed. Teachers' beliefs about teaching and learning STEM, the nature of the STEM disciplines and context have significant effect when examining teachers' beliefs about STEM education. Furthermore, a STEM Pedagogical Content Knowledge (STEM PCK) framework is developed based on teachers' practices. It has been revealed that teachers' orientations toward STEM education is related to all sub-elements of STEM PCK. The framework developed in this research defines STEM PCK comprehensively and reveals the relationships between the elements clearly. During the research, a change was observed in the practices of the teachers in a way that highlights the student-centered teaching approaches and the relationships between disciplines. The findings of this research found out professional development courses that consider the conditions of the institutions where teachers work can be effective in the professional development of teachers. Professional development programs can be rich and effective when they are being oriented towards in-class practice as well as theory, allow teachers to reflect, and support teachers to work collaboratively. It was concluded that the considering teachers' pedagogical content

knowledge and pedagogical beliefs together with their practices was contributed significantly to the research about STEM education.

Keywords: elementary teacher, integrated STEM education, pedagogical content knowledge, pedagogical belief, professional development program

ÖZET

Bu çalışmanın amacı, sınıf öğretmenlerinin bir mesleki gelişim kursuna katılma ve sınıflarında FeTeMM (Fen, Teknoloji, Mühendislik, Matematik) öğretimi gerçekleştirme süreçlerinde pedagojik alan bilgilerinin ve pedagojik inançlarının ve sınıf içi pratiklerinin alt boyutları ile incelenmesidir. Yapılan araştırmalar öğrencilerin gelecekte küresel ekonomide yer edinmek için teknolojiyi geliştirme ve tasarlamada, inovasyonda ve bilimsel okuryazarlıkta bilgilerini geliştirmelerinin önemini vurgulamaktadır. Btüşünleşik STEM öğretimi ile öğrencilerin kendi sosyokültürel koşulları ile ilişkilendirerek bu disiplinlerdeki bilgi ve beceri ve ilgilerini artırmak ve nihayetinde STEM alanlarına giriş yapmalarını sağlamak mümkündür. Öğrencilerin ilk yıllarında doğuştan getirdikleri merak ve sorgulama becerilerinin yönlendirilmesi bu alanlardaki başarılarını artıracak ve sonraki öğretim yıllarındaki başarılarını belirleyici rol oynayacaktır. İlkokul öğrencilerinin potansiyellerini geliştirmeleri -özellikle de düşük sosyo-ekonomik düzeydeki bölgelerde tek akademik desteğinin öğretmeni olması nedeniyle- sınıf öğretmenlerine bağlıdır. Bu nedenle sınıf öğretmenlerinin STEM öğretimlerine dair inanç ve bu alandaki bilgilerinin pratikleri ile iç içe incelenmesi önemlidir. Sürekli gelişen bu alanda öğretmen bilgi ve becerilerinin de sürekli değiştiği göz önüne alındığında öğretmenlerin STEM öğretimlerinde desteklenmelerinin önemi ortaya çıkmaktadır. Bu amaçla bu araştırmada sınıf öğretmenlerinin STEM alanlarındaki inanç ve bilgilerini geliştirmeye yönelik bir mesleki gelişim programı kapsamında öğretmenlerin bilişsel özelliklerini ve pratiklerini incelemiştir. Araştırmada yanıtları aranan sorular şunlardır:

1. Sınıf öğretmenleri STEM eğitimine ilişkin hangi pedagojik inançları taşımaktadırlar ve mesleki gelişim sırasında bu inançları nasıl değişmiştir?

2. Sınıf öğretmenleri STEM eğitimine ilişkin hangi pedagojik alan bilgisine sahiptirler ve mesleki gelişim sırasında bu bilgileri nasıl değişmiştir?

3. Mesleki gelişim programı öğretmenlerin pedagojik alan bilgisi, pedagojik inançları ve sınıf içi pratiklerini nasıl etkilemiştir?

Bu araştırmada durum çalışması araştırma deseni olarak kullanılmıştır. Bunun amacı nitel durum çalışmalarının, gerçek yaşama dayalı bir olay ve olgunun derinlemesine ve gerçek bağlamının özellikleri göz önüne alınarak incelenmesine izin vermesinden kaynaklanmaktadır.

Bu araştırmaya 2018-2019 akademik yılının yarıyıl tatili ve ilkbahar döneminde İstanbul'da bulunan bir devlet okulunda sınıf öğretmenliği yapan 3 öğretmen katılmıştır. Araştırmacı mesleki gelişim programını Putnam and Borko'nun (2000) geliştirdiği çoklu bağlamlar modelinin özelliklerine dayandırarak oluşturmuştur. Yarıyıl süresince mesleki gelişim kursu uygulanmış, devam eden dönemde ise FeTeMM modülleri öğretmenler tarafından geliştirilip uygulanmış ve uygulamalara yönelik yansıtma yapılmıştır. Bu süreçte araştırmacının öğretmenlere olan desteği devam etmiştir. Çalışmanın veri kaynaklarını; mülakatlar, gözlemler, doküman analizi (öğretmenlerin fen ve matematik otobiyografileri, sınıf içi etkinlikler, görseller, ölçme- değerlendirme araçları), ses kayıtları ve video kayıtları ile veriler toplanmıştır. Veri analizi karşılaştırmalı analiz teknikleri ile yapılmıştır. Araştırmanın bulguları, öğretmenlerin FeTeMM öğretimine yönelik pedagojik inançlarının ve pedagojik alan bilgilerinin mesleki gelişim kursu ile değişip geliştiğini ortaya koymuştur. Bunun bir sonucu olarak öğretmenlerin pratikleri de değişmiştir. Ayrıca bu araştırma, öğretmenlerin FeTeMM öğretimine ilişkin inançları incelenirken, öğretmenlerin öğrenme ve öğretmenin doğasına ilişkin inançları ve FeTeMM disiplinlerinin doğasına ilişkin inançlarının yanı sıra bağlama yönelik inançlarının da önemli bir etkisi olduğunu ortaya koymuştur. Diğer yandan bu araştırmada öğretmenlerin uygulamalarına dayalı olarak FeTeMM Pedagojik Alan Bilgileri (FeTeMM/STEM PAB) çerçevesi oluşturulmuştur. Öğretmenlerin STEM öğretimine yönelik yaklaşımlarının FeTeMM PAB'ın tüm alt ögeleri ile bağlantılı olduğu ortaya koyulmuştur. Bu araştırma kapsamında geliştirilen FeTeMM PAB çerçevesi, FeTeMM PAB'ı kapsamlı bir şekilde tanımlamakta ve ögeler arasındaki ilişkileri açıkça ortaya koymaktadır. Öğretmenlerin araştırma süresince uygulamalarında öğrenci merkezli öğretim yaklaşımları ve disiplinler arasındaki ilişkileri öne çıkaracak şekilde değişim gözlenmiştir. Bu araştırmanın bulguları, öğretmenlerin çalıştıkları kurumların koşullarını göz önüne alan, teorinin yanı sıra uygulamaya dönük ve yansıtma yapmalarına izin veren, öğretmenlerin işbirlikli çalışmasına olanak sağlayan mesleki gelişim kurslarının öğretmenlerin mesleki gelişimlerinde etkili olabileceğini ortaya koymuştur. Araştırma sonunda öğretmenlerin pedagojik alan bilgisi ve pedagojik inançlarının pratikleri ile birlikte ele alınmasının önemi vurgulanmıştır.

Anahtar kelimeler: sınıf öğretmeni, bütünleşik FeTeMM/STEM eğitimi, pedagojik alan bilgisi, pedagojik inanç, mesleki gelişim programı

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CHAPTERS

1. INTRODUCTION

In this section, the background, the purpose, and the significance of the study, as well as the definitions of terms are explained.

1.1. Background to the Study

In 2015, a handmade craft rose to 78.000 feet to capture the view from the edge of the space. The craft was built out of wood and broken arrow shafts by two sisters aged 10 and 12. There were a flight computer tracking their craft, two GoPro cameras, and a picture of their cat next to a Lego R2-D2 attached to a weather balloon filled with helium (Risley, 2015).When judged from the fact that elementary students may create their own spacecraft, it can be understood that technology revolutionizes our entire society. Yet, when this story was read to elementary school teachers at a teacher STEM workshop in 2017 in Umraniye, the teachers immediately developed a mindset about how unique this story is; nevertheless, it cannot be implemented in Turkey. When they have the opportunity, students can come up with creative solutions to existing problems by using knowledge from different disciplines in relation to each other. Yet, they need guidance. Especially in regions with low socio-economic level, as in the district of Umraniye mentioned here, teachers are at the forefront of the limited resources that support primary school students academically. For this reason, teachers' understandings and approaches play a decisive role in students' STEM learning. This occasion shows that, with technological revolutions, there are both opportunities and challenges for educational landscape. With an increased need for knowledge and innovation to create a sustainable society, our education system faces major challenges. As a researcher, in this study, my motivation is to analyze the quality, motivations and practices of the teachers so that having a perspective on STEM education in Turkey.

Teacher qualification plays a very important role in enabling students to discover and develop their potential. However, opportunities for students from low socio-economic families to explore and develop their capacities in STEM fields are very limited. It has been proven by research that the application of student-centered approaches such as integrated STEM education will contribute to the conceptual learning of the student by establishing the connection between

these disciplines without breaking away from real life (Freeman et al., 2014; Guzey et al., 2017), accordingly the teachers' application (naturally, public school teachers) plays a critical role in the learning of the students. Especially, it should be considered that the learning fields of students attending public schools are limited to schools. Beliefs of teachers in STEM learning and pedagogical content knowledge in teaching these disciplines are the main factors that will affect their classroom teaching and thus students' learning. Teachers' beliefs in their students' learning capacity and skills come to the fore in the planning of instruction. In the process of applying the lessons they have planned; teachers apply to pedagogical content knowledge with toolboxes and act as a source for students' learning in line with their proficiency. For this reason, the future of these students, whose only source of learning is elementary teachers, depends to a great extent on the education they receive during their basic education, and therefore on the qualifications of their teachers. When the qualifications, motivations and practices of teachers are examined in consideration of the conditions they are in, they will give important clues about STEM education.

It has become important to develop new generation's knowledge and skills in designing and developing technology, innovation, and scientific literacy to secure their positions in the global economy during the last decades (Baran et al., 2016). Therefore, it has also become important for governments to take an action for high quality Science, Technology, Engineering and Mathematics (STEM) education in all grade levels. Not only governments but also educators, business and industry organizations emphasize the importance of improving STEM education to solve current and future social and economic issues (Caprile et al., 2015; Honey et al., 2014; Pak Karaca & Küçükoğlu, 2014).

With increasing attention to STEM education, the improvements in the quality of curricula and instructions are rapidly becoming. In turn, numerous new programs have emerged, curricula have been changed and, new instructional materials and specialized schools have been designed (Corlu, 2017). According to a report published by National Academy of Science, these initiatives address to one or more of the STEM subjects separately, while there are increasing calls for emphasizing connections between and among the subjects. Moreover, issues can make the STEM subjects more relevant to students and teachers in the context of the real world. Teaching STEM topics in real world context may increase students' interest, achievement, and persistence. These outcomes are expected to increase the number of students who consider a

career in a STEM-related field and will better prepare students for college and workforce (Honey et al., 2014). Moore (2008) clearly articulates the role of the integration of these four disciplines in a real-world context and notes that the overall purposes of the STEM education is to prompt students to enter the STEM fields. According to Moore (2008):

"STEM is a merging of four disciplines to "deepen student understanding of each integration discipline by contextualizing concepts; broaden student understanding of STEM disciplines through exposure to socially and culturally relevant STEM contexts; and increase interest in STEM disciplines by increasing the pathways for students to enter the STEM fields."

According to National Research Council (NRC) there are three goals defined in K-12 STEM education, which are (1) expanding the STEM capable workforce, (2) increasing advanced training and careers in STEM fields, and (3) increasing scientific literacy for all students (NRC, 2011). In other words, overarching goal of STEM education for the schools is to supply high quality STEM education to the students, therefore engaging students in content, and preparing them for the post-secondary education and workforce.

Over the last decade, STEM has been a remarkable phenomenon (NRC, 2003). The reason is many global challenges including "climate change, overpopulation, health, biodiversity, and declining energy and water sources", required to be solved with an interdisciplinary perspective supported by science and technology. However, improving STEM education becomes substantial to meet the growing demand of workforce in these fields in many countries (English, 2016; Marginson et al., 2013). Governments consider STEM disciplines critical for workforce and a tool of becoming better in global economic competition (Brown, 2003; Marginson et al., 2013). To remain competitive in a growing global economy, to take an action, and to solve complex problems mentioned above concerning all nations, students' achievements need to be increased in STEM fields (Wang et al., 2011).

In parallel with the progress in STEM education all around the world thanks to both governments and the international institutions, Turkey also took action to accelerate educational improvement to create the conditions that make effective teaching and learning possible. In the lights of the new findings in education, The Ministry of National Education (MoNE) put a new approach and curriculum in 2005 into effect (MoNE, 2005). According to this reform in education, the teaching methods and textbooks have been changed. As stated in a recent report

published by MoNE, the expectation from the members of a society has been updated in accordance with the recent developments in science and technology. These developments and progresses necessitate adding three main themes to the curriculum in addition to basic standards: (1) cognitive abilities such as problem solving, critical thinking, authentic thinking, conducting researches, (2) social abilities such as social and cultural participation, entrepreneurship, communication, empathy, (3) personal abilities such as self-confidence, determination, self-regulation, leadership (Board of Education, 2017). This report also emphasizes the importance of 21st century skills including mathematical proficiency, scientific and technological proficiency, digital proficiency, sense of initiative and entrepreneurship.

Recent reports in Turkey state that the increasing importance of trained manpower in STEM fields is emphasized and the need for preparing students for the STEM competencies, increasing their knowledge and skills in these areas are underlined (Akgündüz et al., 2015; MoNE, 2009; TÜSİAD, 2014). The implementation of STEM education in the context of Turkey differs with school types and levels. However, it is known that only a minority of students meet the international standards in STEM education in Turkey and most of these students are educated in specialized schools (Corlu et al., 2014).

Elementary education, on the other hand, plays a significant role on how individuals begin to develop perceptions and knowledge about STEM disciplines during elementary schools (National Research Council, 2007). It shows us the importance of STEM education in elementary levels. Young learners have an innate interest and curiosity, which are necessary to be worked up, so that they will have a positive attitude towards STEM, and it leads them to learn more about STEM (Maltese & Tai, 2011). High quality STEM curriculum and instruction are promising areas in elementary school education especially with enough support to elementary teachers' efficacy to teach STEM (Nadelson et al., 2013). Moreover, recent developments in the STEM education worldwide have given rise to a need to deeply understand teachers' perspective of STEM integration, how integrated STEM curriculum might be applied, in what ways teachers integrate these four disciplines in their lesson plans and in-class practices, how the implementation process is going on and what kind of benefits there are from the teachers' eyes (Herscbach, 2011). Research which examines the prerequisite skills, beliefs, knowledge bases, and experiences necessary for teachers in the classroom is limited in STEM education (Frykholm & Glasson, 2005). It is one of the biggest educational challenges to have

only a few general guidelines or models for teachers to follow regarding implementing STEM integration approaches in their classroom (Wang et al., 2011). Thus, further research is needed on integrated STEM education to foster teachers' professional knowledge and to understand how effectively the methods can be implemented by teachers (Kelley & Knowles, 2016). The purpose of this study is to explore how a STEM- focused professional development program affects teachers' pedagogical content knowledge and pedagogical beliefs about STEM education and their teaching practices. The results of this case study will contribute to the literature on school-based educators' experiences and perceptions for implementing integrated STEM education in elementary school. The lessons obtained from this case study may provide teachers at the elementary level with a better understanding of how to integrate STEM education into the classroom.

1.2. Research Questions

Considering the overall purpose, this study attempts to answer the following research questions:

1. What beliefs do elementary teachers have about STEM education and in what ways have teachers' beliefs been changed during the PD?
2. What pedagogical content knowledge do elementary teachers have about STEM education and in what ways have teachers' beliefs been changed during the PD?
3. In what ways does the professional development course contribute to teachers' PCK, beliefs and in-class practices?

1.3. Significance of the Study

The significance of the study mainly stems from the need to understand the processes elementary teachers go through in the teaching of integrated STEM modules in their classes. STEM integration is an innovative way of thinking about teaching mathematics and science in K-12 and has a great potential to empower students in these fields (Wang et al., 2011).

Many studies have been carried out about the positive effects of integrated curriculum, which emphasizes the significance of integrated STEM, on students' attitudes toward school

(Bragow et al., 1995; Suprapto, 2016), student achievement (Becker & Park, 2011; Sullivan & Heffernan, 2016), and professional development of teachers (Capraro et al., 2016; Shernoff et al., 2017; Wang et al., 2011). Furthermore, many organizations such as NCTM, OECD, World Bank and UNESCO have underlined the importance of STEM education and the need for the professional development of teachers in their reports and suggested standards for school curricula (Marginson et al., 2013).

Professional development programs for in-service teachers have become vital for developing and improving integrated curriculum and making STEM integration sustainable (McHugh et al., 2018; Wang et al., 2011). As indicated previously, this study is about designing and implementing a professional development course for in-service teachers. In-service teachers were not only provided with theoretical knowledge, but they were also supported to apply what they learned in practice. Therefore, understanding the problems arising during the implementation process in depth will help to develop strategies to equip teachers with necessary tools and assisting them to cope with the challenges of the teaching integrated STEM methods better. Additionally, triangulation of data will provide us with a better understanding about in what ways teachers' perception is translated into practice, what challenges teachers face, the solutions they produce and the progress they make in the process.

Researchers pointed out that there are very limited studies about how teachers perceive the integrated STEM education and how this perception is reflected in their practice in the classrooms and announced that additional studies are needed in the preparation and development of teachers in this field (Arnold & Schell, 1999; Capraro et al., 2016; McHugh et al., 2018; Shernoff et al., 2017).

This study investigates elementary school teachers' teaching practices while implementing a series of integrated STEM modules in teaching process. In analyzing the classroom teaching practices, I focused on several issues, including teachers' perceptions about the STEM education they received, the experiences they undergo regarding classroom processes, their professional development, relationships with students, teaching performance, assessment methods, as well as their classroom discourse regarding the implementation of STEM modules. Many researchers pointed out that there are many studies regarding integrated STEM education in the US, UK, and Australia (Blackley & Howell, 2015). However, only a few studies could

be found in Turkey (Akgunduz, 2016). There are also relatively few studies specifically focusing on in-service teachers' professional development in integrated STEM education. The results of the study may serve as a steppingstone for further studies on the professional development and implementation of integrated STEM curriculum.

In addition to this, a need for studies focusing on various issues such as how teachers develop and implement curriculum integration, finding new strategies and curriculum alignment for successful STEM implementation, learning materials and assessment tools for the teaching of integrated STEM curriculum in elementary classes has been voiced (Czerniak et al., 1999; Harrigan, 2014; McKenna, 2007; Smith, 2009). The current study has depicted the curriculum integration from planning to implementing and evaluating in the elementary school setting. Therefore, this study is significant in terms of picturing the process of curriculum alignment. This study gives such an overview of the implementation process. Findings from this study may contribute to the literature in terms of providing suggestions for the principles of designing effective professional development modules about integrated STEM education and provide first-hand experience about the effects of professional support on teachers' in-class practices.

Moreover, the results from this case study will contribute to the literature on school-based educators' experiences and perceptions for implementing integrated-STEM education in elementary school. The findings of this study might serve as a base for understanding the nature of in-service teachers' classroom practices regarding the integrated-STEM education. The lessons learned from this case study may also provide researchers a better understanding of the effective pedagogical principles about the integrated-STEM education that teachers need, especially working in socioeconomically disadvantaged school districts.

1.4. Definitions of Terms

Integrated STEM education: "Deepen student understanding of each integration discipline by contextualizing concepts; broaden student understanding of STEM disciplines through exposure to socially and culturally relevant STEM contexts; and increase interest in STEM disciplines by increasing the pathways for students to enter the STEM fields" (Moore, 2008, as cited in Wang et al., 2011).

PCK: The combination of content knowledge and pedagogical knowledge to make subject matter comprehensible to students (Shulman, 1986)

Content knowledge: A facet of PCK that refers to the amount and organization of facts and concepts, including an explanatory framework (Shulman, 1986).

Context: The circumstances that form the setting for an event, statement, or idea, and in terms of which it can be fully understood (Cherny, 2014).

Knowledge of context: A construct of pedagogical content knowledge that is concerned with the teachers' knowledge of the instructional environment (Feldman and Herman, 2015).

Beliefs: Psychological constructions that include understanding, assumptions, images, propositions that are felt to be true (Kagan, 1992; Richardson, 1996).

Teacher beliefs: The internal system of perspectives and values that affect a teacher's attitudes and teaching (Opperman, 2015).

Self-efficacy beliefs: The belief that one has or does not have the ability to produce an intended effect (Opperman, 2015).

Orientations toward teaching: A teacher's interrelated set of knowledge and/or beliefs about "the goals and purposes of teaching, (the nature of) discipline, and teaching and learning" (Friedrichsen et al., 2011, p. 373).

Teachers' belief about teaching and learning: Teachers views on their preferred ways of teaching subjects, and views on how it is learned.

Traditional beliefs: A knowledge transmission view, in which teaching is seen as a process of knowledge transmission and students receive knowledge from teachers passively (Blömeke & Kaiser 2014; Tatto, 2008).

Constructivist beliefs: (non-traditional beliefs) A view in which teaching is seen as facilitating students' knowledge construction (Blömeke & Kaiser 2014; Tatto, 2008).

Teacher cognition: Cognitive dimension of teaching, what teachers believe, know, and think (Borg, 2003, p. 81).

Professional Development (PD): An educational experience "related to an individual's work in which people participate in to learn and apply new knowledge and skills that will improve their performance on the job (Mizell, 2010).

In-class practice: (classroom practices/ teaching/ instruction/ instructional practices) What happens in a teacher's classroom.

Teacher-centered instruction: (rote learning/ rote memorization/ lecturing/ traditional instruction) An approach where teachers' responsibility is seen as delivering knowledge, using direct instruction (Jaworski, 2001).

Student-centered instruction: (innovative methods/ constructivist instruction): An approach where studens engage actively in meaningful and real life related topics so they can make conjectures, investigations (Jaworski, 2001).

Hands on learning: An approach where students learn by doing. Students handle materials and manipulate objects (Haury & Rillero, 1994; Rutherford, 1993).

Conceptual understanding/knowledge: An integrated and functional grasp of ideas, comprehension of concepts, operations, and relations" (Kilpatrick et al., 2001).

Procedural understanding/knowledge: Understanding that is focused "on skills and step-by-step procedures without explicit reference to mathematical or scientific ideas" (Ashlock, 2001, p. 8)

Formative assessment: The process used by teachers and students to recognize and respond to student learning in order to enhance that learning, during the learning (Cowie & Bell, 1996, p. 3)

High stake tests: Large-scale tests that is used for placement of students into higher level educational institution. These exams consist of multiple-choice questions and determine student achievement level (Kumandas & Kutlu, 2010).

1.5. Abbreviations

MoNE: Ministry of National Education

STEM: science, technology, engineering, mathematics

PD: professional development

PB: pedagogical beliefs

PCK: pedagogical content knowledge

TA: teaching assistants

1.6. Limitations of the Study

This study has several limitations that need to be acknowledged. First of all, since there is a time limitation to complete a PhD dissertation, the duration of the professional development program was limited to a spring break and one semester. In this case study, teachers' pedagogical beliefs and pedagogical content knowledge along with their practices have been analyzed and the impact of professional development course has been examined. Further research should also explore in what ways teachers' development occur through longitudinal studies.

Secondly, teacher knowledge and beliefs generated from this study is contextually based. The goal of this research is to produce descriptive and analytical accounts of three teachers' integrated STEM modules—this does not imply that other STEM classes are like the ones studied. In other words, there might be other factors effective in other teachers' cognitions and practices in different contexts that require further investigation.

2. LITERATURE REVIEW

2.1. Purpose of the Literature Review

The purpose of literature review was to find studies containing quantitative, qualitative, mixed methods which are published in peer-reviewed journals since 2000 to identify elementary teachers' beliefs, PCK of STEM education and factors that affect STEM instruction in elementary education.

The following criteria have been utilized while selecting research studies:

1. Research must:
    a. investigate teachers' beliefs, the changes in their beliefs after attending a professional development or a course of methods and whether their implementations reflect these changes afterwards,
    b. examine teachers' pedagogical content knowledge, the changes in their PCK after attending a professional development or a course of methods,
    c. aim to identify the integrated STEM education, the extent and affordances of the integrated STEM education, teachers' roles, challenges, and successes in implementing integrated STEM education
    d. examining teachers' STEM pedagogical content knowledge.
2. Articles must be published in a peer reviewed journal,
3. Articles must be published between 2000 and 2020.

In this literature review, the primary focus was on elementary in-service teachers' professional development and practices of integrated STEM education; however, because of limited research in this area, research conducted with pre-service teachers and middle and high school teachers were also included. On the other hand, it was aimed to include teachers' beliefs and PCK in integrated STEM education in this literature review; Yet, due to the lack of research

in this area, research conducted within only science, only math or a combination of both disciplines in STEM were also included.

The online databases used for literature research included ERIC (EBSCOhost), Web of Science and Google Scholar. The keywords that were used for research about teacher knowledge are “elementary/primary teacher, pedagogical content knowledge and STEM. “Teacher knowledge, practice and professional development” words or phrases were also used to find relevant articles. Five articles were found in the databases. Due to the lack of the study in the STEM PCK in elementary education, research conducted about PCK within the single and multiple STEM disciplines were also added. To identify the relevant studies, two main disciplines related to the current study were focused on. Mathematics PCK and Science PCK in elementary education were reviewed from the databases. Next, the PCK research conducted with one of the sciences and mathematics disciplines were also added. For example, research conducted about PCK in the intersection of mathematics and engineering were added. A total of 37 studies were selected for the review for the current study focusing on STEM education, pedagogical content knowledge, professional development, and educational instructions.

Furthermore, to research teachers’ beliefs, the literature was searched with the following keywords: teacher beliefs, primary/elementary teacher, professional development, beliefs about the nature of learning, beliefs about the nature of teaching process and instructions, belief and context, belief and the nature of mathematics and belief and the nature of science. Research in this topic was refined by considering if they include mathematics, science, engineering, and technology disciplines. A total of 44 studies were selected for review on teachers’ belief in STEM education. Moreover, for research about teachers in STEM education, the following keywords were used: “STEM instruction”, “elementary/primary teacher”, “teaching and STEM”, “teach and STEM”. As anticipated, all of the articles were published after 2008, even though the researcher did not filter out based on the publication date. A total of 26 articles were found relevant to the review.

Additionally, I aimed to address the studies focusing on the relationship between the foundations of the practice of teaching STEM including teachers’ knowledge and beliefs(Ernest, 1989). To do this, the literature was searched with the following keywords: “belief,” “pedagogical content knowledge”, “teacher”, “elementary/ primary teacher”,

"professional development", "instructional practice". 54 articles were found relevant in the literature which examines the relationship between PCK and teachers' belief in integrated STEM education in an elementary setting.

The critical review of the literature was inquired in four subsections based on the focus of the selected articles.

1. **STEM education:** In this section, several definitions of STEM education have been identified and discussed from an educational perspective. Conceptualizing ideas about STEM education has been examined under several subsections: educational, political, and societal, economic, popular, and historical.
2. **Teacher knowledge and PCK:** This section analyzed the elements of teacher knowledge. Different types of teacher knowledge, in particular pedagogical content knowledge and its components, in STEM education and their relationship with the in-class practices have been addressed. Additionally, teachers' role in promoting student learning in STEM education, instructional models and teachers' implementations were examined.
3. **Teachers' belief:** This section examines teachers' beliefs about the nature of learning, the nature of teaching and instructional strategies, the nature of each discipline in STEM education and beliefs about context in STEM education.
4. **Teachers' professional development:** In this section, effective ways of developing teacher practices were identified again specifically focusing on integrated STEM education.

2.1.1. STEM Education

The notion of STEM has been widely used among several stakeholders such as educators, industrial and policymaker communities. While each of the stakeholders has their own conceptualization about what STEM is and why it is important and how it should be implemented, this literature review aims to explain STEM with a broad perspective and subsequently focuses on STEM in educational context.

2.2. Conceptions of STEM from Several Perspectives

It is an important issue to identify several meanings and contexts of STEM education and to be clear about what this study connotes with STEM education since it has been an ongoing research area and there is a lack of substantial agreement on what it is. A profound literature review has identified five conceptualizations of STEM depending on where to seek the answer: economic, political, historical, educational, and popular

From an economic perspective, it is seen that STEM education comes to the foreground since countries need quality STEM education in order to hold a place in global economy. While many nations have concerns about meeting the demand of global economic challenges, concerns about improving STEM education remain acute (Kelley & Knowles, 2016). Considering the relation between current and future shortages in the STEM workforce and global economy, promoting STEM education remains important for industrial and policy communities (Akgunduz et al., 2015).

Three main reasons are identified in the literature for countries to seek to spur more development in STEM fields (Atkinson & Mayo, 2010). Firstly, development and innovation in these fields lead countries to economic growth. For instance, in a recent report, it has been found that technological innovation accounts for as much as 75 percent of the growth in the American economy since World War II (Glassman, 2010). Besides, it has been identified in another study that information technologies have accounted for half of the productivity over the last decades (Atkinson & McKay, 2007). On one hand, the development in STEM fields destroys lower-wage, lower productivity jobs; on the other hand, it creates more productive jobs which require high skills. Secondly, countries seek development in innovation to remain competitive in international markets. Thirdly, development in STEM fields provides societies with a better health care, education, transportation, and environmental protection, therefore, increasing the welfare of the society. STEM education plays a key role in promoting sustainable development for economies, as science and technology-based innovation is only possible with a workforce educated in STEM fields (Atkinson & Mayo, 2010; Soylu, 2016). As a report published by OECD revealed, “Education systems play a broad role in supporting innovation because knowledge-based societies rely on a highly-qualified and flexible labor-force in all sectors of the economy and society. Innovation requires the capacity to learn continually and

upgrade skills" (OECD, 2010). Therefore, policy makers and industry leaders emphasize on qualified manpower in STEM fields and advancing competencies in these fields (Aydeniz & Bilican, 2018; Kelley & Knowles, 2016). As can be seen, education, especially quality education in STEM fields, matters for economic development.

From a political perspective, it is seen that many governments have established national research programs to challenge attempting interventions considering the shortage of evidence on their effectiveness e.g., US, European countries, Australia, Canada (Committee on STEM Education National Science and Technology Council, 2013; Krishna, 2013; Larrouturou & Rocard, 2007; Office of the Chief Scientist, 2013). Governments have taken an action to improve their educational processes and international organizations have accelerated their research in STEM education (Akaygun & Aslan-Tutak, 2016).

From a historical perspective, integrated STEM education is affiliated with integrated curriculum (Corlu et al., 2014). When integrated curriculum-based studies are examined, it can be said that 1927 was the starting point in this regard. In the study he conducted as a post-graduate thesis, Smith focused on the integrated personality and the concept of holistic learning asserted in project method. The uncontrolled experimental method was used in the research. It was emphasized in the research that students perceived knowledge as a whole, and they learned the knowledge in relation to the environment and other disciplines. The effects of these findings were also underlined from an educational perspective.

From a historical perspective, when studies about integrated curriculum are examined, it is observed that the progressive approach of John Dewey and the practices he applied in his own experimental school (Dewey Laboratory School at the University of Chicago) are pioneering attempts in this field. Dewey's integrated curriculum emphasizes, on the one hand, learning community by addressing social needs and focuses on fostering students' intellectual development on the other hand. According to him, instead of fitting students into the current curriculum, teacher guides students to experience new knowledge without dictating one way (O'Grady et al., 2014).To fully grasp the foundations of integrated curriculum, it is important to understand how Dewey developed his thesis about the structure of school and its relationship with the social setting. Dewey created and directed the Lab School at the University of Chicago from 1894 to 1904 to shape his ideas about education. Lab School had a living laboratory role

for him as he observed, thought about and theorized his understanding of education. Dewey concluded that both curriculum and the school needed a reconstruction to enact his understanding of education which should originate from self and concern learning to live with others in a social setting (O'Steen et al., 2002).

"I believe that the only true education comes through the stimulation of the child's powers by the demands of the social situations in which he finds himself… The child's own instincts and powers furnish the material and give the starting point for all education" (Dworkin, 1967, p. 20).

As can be understood from Dewey's statement, while implementing integrated curriculum, the starting point should be students' prior knowledge, conceptual thinking interests and needs. Besides, Dewey underlined that, students discovered current issues and became a part of the solution by assuming responsibility during the process, which meant that student-based approaches were significant. With the integrated curriculum, students' input to the curriculum, shaping curriculum around students' interests and current issues in their lives, real-life problem solving, project-based learning and cooperative process are valued (An & Tillman, 2014; Beane, 1997). From a general perspective, it is seen that integrated STEM education today is based on the integrated curriculum Dewey defined and implemented in his own day.

As well as placing the student in the center of education and permitting experimental learning, adopting integrated curriculum has led many countries in the course of history (e.g., Hong Kong, Shanghai, Singapore, Korea, Canada, Japan) to highest performances among OECD counties in PISA (Program for International Student Assessment) (Drake & Savage, 2016). For example, Finland, which adopted curriculum integration in 1970s, has ranked at or near the top of the PISA (Halinen, 2016; Niemelä & Tirri, 2018). Canada is another high-ranking country which has embraced integrated curriculum for years. Korea, on the other, one of the top-ranking countries in the world, has shifted to integrated curriculum since 2009.

From a popular perspective, STEM approach is defined as aiming to popularize and disseminate science and engineering to educated laymen (Asik et al., 2017). In addition, Corlu noted that popular science, science centers, robotics competitions or maker movement can be considered as popular STEM (Corlu, 2017). On the other hand, Asik and colleagues (2017) explained that with a current project STEM approach is aimed to cultivate production and

innovation culture in societies instead of consumption culture. In the context of this project, several initiatives, such as teacher professional development program, science fair, producing films with the popular cartoon characters, were launched. Therefore, the initiatives which lead public to gain scientific knowledge of or to increase interest in any field in STEM initiative can be seen as popular. The distinction of classification between popular and educational STEM initiative, then, could be made by considering whether the activity is linked to a curriculum or learning outcome, or it causes students to be interested in science (Corlu, 2018).

Finally, when considered from the focus of the study, that is, from an educational perspective, it is necessary to examine the meanings of both the term integrated and the term STEM to understand "integrated STEM education" better. According to Jacobs (1989), interdisciplinary means conscientiously applying methodology and language from more than one discipline to a theme, topic, or problem. On the other hand, the term STEM has multiple descriptions in the education setting. Among them is included “teaching STEM subjects separately” (Benitti & Spolaôr, 2017; Gough, 2015; Stevenson, 2014) “teaching STEM subjects as they relate with each other to solve real world problems which includes content from all four disciplines” (e.g., Labov et al., 2010; Sanders, 2009) and “indicating the equity issues in education which are related to both integrated STEM education and each of the STEM subjects” (Barton & Levstik, 2003; Morales-Doyle & Gutstein, 2019). Researchers discussed that the lack of consensus on the meaning of STEM comes from the variety of approaches “that have resulted in without coordination and outlets for communication of ideas” (Czerniak & Johnson, 2014, p. 400).

All elements of the above STEM from various perspectives were considered and particularly the second meaning of STEM has been used in this research. Integrated STEM education is defined as:

> “Deepen student understanding of each integration discipline by contextualizing concepts; broaden student understanding of STEM disciplines through exposure to socially and culturally relevant STEM contexts; and increase interest in STEM disciplines by increasing the pathways for students to enter the STEM fields” (Moore, 2008, as cited in Wang et al., 2011).

In educational context, several combinations of integration have been adapted, depending on the researchers' focus upon central disciplines (Aydeniz & Bilican, 2018). For example, in some research, mathematics and science have the central role (Corlu, 2012); in other research, mathematics has the central role (Kertil & Gürel, 2016); in still other research, science and technology have the central role (Engin et al., 2015), whereas other researchers concentrate on technology (Sisman et al., 2020). In the current literature, there are several pedagogical frameworks to reach the desired learning outcomes; these are project-based learning, mathematical modeling, inquiry-based learning, problem-based learning (Leung, 2019; Lou et al., 2011).

Despite the fact that several perspectives and implementation methods are being used, all of the pedagogical methods have a common purpose, which is to integrate learning into content areas to prepare students for the skills and knowledge required to participate as informed members of the society (Crotty et al., 2017; Honey et al., 2014).

2.3. Conceptual Framework and Recent Literature on Teaching STEM

Students and teachers in twenty-first century classrooms face significant teaching and learning challenges in preparing for post-secondary education (Keiler, 2018). In order for teachers to meet this expectation, content knowledge which has been the focus of traditional STEM education, is not sufficient. A robust, in-depth STEM teaching by using student-centered pedagogies is required for students to learn these disciplines with an understanding and becoming competent individuals in these disciplines. Whereas researchers are aware of the effects of teaching in STEM education, there is a lack of studies that examines teachers' practices and understandings which can be studied from many different angles. However, teachers' cognition and development construct the main conceptual framework in this study, because of the fact that teachers' pedagogical content knowledge has impact on the quality of instruction and teachers' pedagogical beliefs guide their decision-makings throughout all steps of the teaching in a complex way (Blömeke and Delaney, 2012). In order to guide the exploration of teachers' cognitions and applications about STEM teaching in elementary school settings, the current study draws on a framework of teachers' pedagogical content knowledge and beliefs.

Examination of STEM education literature at the primary education level shows that research is related to the following topics; analyzing the conceptions of teachers and views on STEM (Akaygun & Aslan-Tutak, 2016; Cinar et al., 2016; El-Deghaidy & Mansour, 2015; Holmlund et al., 2018; Lamberg & Trzynadlowski, 2015; Madden et al., 2016), to in-class practices of teachers (Cohen B., 2018; Dare et al., 2018), to the effect of the approach that teachers have on student success (Crotty et al., 2017), to effective teaching methods used in integrated STEM education (Mustafa et al., 2016), to work on developing curricula materials (Guzey et al., 2016), to various STEM teacher training programs (Bartels et al., 2019) to professional development models for integrated STEM education (Donna, 2012; Guzey et al., 2014; Nadelson et al., 2013), to the role of teachers' knowledge in STEM education (Kaya & Elster, 2019; Van den Kieboom et al., 2013) and to teachers' beliefs (Dönmez & Tasar, 2020).

It is evident from the literature review that many researchers are carrying out studies to understand what kind of conceptualization teachers have regarding STEM education (e.g., Breiner et al., 2012; Radloff & Guzey, 2016; Ring et al., 2017). Basically, there may be many reasons for this; the first reason is that the political and economic roles of STEM education mentioned at the beginning of this chapter which also contribute to the definition and role of STEM education. With these roles, STEM education has a meaning that is still evolving and changing. For this reason, researchers also wanted to examine teachers' views and perceptions about STEM education.

Lamberg and Trzynadlowski (2015) interviewed 7 class teachers in the US to examine teachers' understanding of STEM applications in their research. The findings of the study show that although teachers correctly define the acronym "STEM", they have little knowledge of how STEM education is applied. One of the most common opinion of the teachers is that they see "hands-on activities" as STEM activities but ignore the subject matter in this process. Similarly, El-Deghaidy and Mansour (2015) conducted interviews with 21 different teachers from 21 different schools and collected data in order to examine the perceptions of science teachers about STEM education and the factors that cause STEM education practices in Saudi Arabia. The findings of the study show that all teachers feel unprepared to practice STEM. In addition, most of the teachers who participated in the research didn't have sufficient understanding of the Technology component in STEM education. Another important finding of this study is that science teachers do not feel competent about the nature of other disciplines and their integration

methods. As a result, teachers suggested that they could better support students' conceptual learning by working in collaboration with teachers from other disciplines and engineers instead of attending traditional professional development courses.

Considering the effect of teachers' views on STEM education on the lessons that teachers design and administer, it is clear that it has an important place in STEM education. The designs of a teacher who sees STEM education as hands-on activities are also those that include more hands-on activities, or it is also possible that a teacher who sees STEM education as internal teaching with technology names his work STEM education by including technology in his existing plans. Therefore, it is important to study teachers' perceptions of STEM education. In addition, considering the historical process of the development of STEM education, it is seen that teachers have developed after they start their professional lives. As a natural consequence of this, teachers do not yet have fully defined ideas in this area.

According to another study that was conducted with 118 secondary school teachers in Turkey, 56 % of the teachers had never heard about the concept of “Integrated STEM Education”. The study predicted that professional development courses for STEM would increase the awareness of teachers towards STEM and therefore would have a positive effect on features such as interest, attitude, and professional orientation in students. Another striking result of this study is that while newly graduated teachers had a positive awareness of STEM, teachers who had been working for 10 years or more had negative perspectives. The research revealed the necessity of professional development programs (Çevik et al., 2017).

Studies of teachers and successful applications on the concept of "STEM education", which is a new concept for them, play a critical role in the work to be done with teachers. At this point, the role of professional development courses designed for teachers comes to the fore. The earlier emergence of STEM education in the USA for political reasons has created a general awareness among the teachers who work there. In other countries including Turkey, various ways and methods are followed to strengthen STEM education. Practices made to strengthen STEM education were not limited only to the studies conducted in the school, but also started to be seen in after-school programs.

Although the importance of the effectiveness of teaching in STEM education is a well-known fact, examining teachers’ experiences in-depth, discovering the problems they face in

the process, and evaluating students' learning from the eyes of teachers make it possible to support them in their professional development.

With their multiple case study, Dare and colleagues (2018) observed the integrated STEM curriculum units of 9 teachers in their classes and studied what they experienced. Science teachers of 4-8 grades, who participated in this study, joined in the summer professional development program for 3 weeks and improved their engineering design and data analysis skills; they also developed in-depth understanding of the fields of science of their choice (life, earth, physical science) and worked on STEM curricula development. Teachers applied the STEM curricula, which they developed during this study, in their classes. The findings of the study revealed that all the teachers had difficulty in integrating all disciplines (S, T, E, M) into their lessons in a balanced way. Besides, although the issue of linking STEM content disciplines had been studied in professional development, all teachers stated that their students had difficulties in establishing interdisciplinary relationships. On the other hand, it was observed that teachers mostly focused on science content and sometimes included engineering and mathematics in their applications. At the same time, teachers stated that their students had difficulties in processing the learned subjects. Another important finding of this study was that all the teachers who participated in the study stated that their students were motivated and focused during this STEM application process. Similarly, Cohen (2018) discovered that while the mathematics and science were typically used, technology and engineering were used less widely. On the other hand, teachers stated that while they felt safe in teaching in the fields of science and mathematics, they felt less secure in teaching the subject of engineering. In addition, it was observed that teachers who felt more competent in teaching STEM curriculum used it more deeply.

The research conducted has shown that the way to effectively perform student learning in STEM education is that teachers should be qualified and should have qualified support. If we look more closely at the requirements of effective STEM education, it can be seen that there are many methods implemented by teachers for students to learn the content more deeply.

In their study examining effective methods that can be applied in STEM education, Mustafa and colleagues (2016) examined 187 articles in the field of STEM education and identified 3 main methods that increase learning, motivation, interest, and perception in

students. According to the findings of the study, the project-based learning approach is the most effective method in terms of participation, developing students' critical thinking skills and problem-solving skills in real life situations. Other effective methods are inquiry-based learning and problem-based learning. Reviews of recent literature show that with the integrated curriculum, students' interests in mathematics, science and engineering, their success and motivation in these courses increased. Searching for effective methods that enable students to learn better in STEM education is stated as necessary.

The research carried out by Kertil and Gurel (2016) is important in terms of examining effective methods in STEM education. The researchers compared the STEM education which use project-based learning and mathematical modeling and reported their suggestions for the application of these methods. The researchers explained these methods with the STEM integration forms previously (Bryan et al., 2015). They defined the project-based learning method as content integration and the mathematical modeling method as context integration. Although both activities are similar in that they allow students to learn conceptually, explore issues related to more than one discipline, and work collaboratively, the application of the mathematical modeling method has been observed to be easier when the current school structure is considered.

The facts that supporting teachers' professional development is important, that they are in an ongoing professional development and that the professional development programs they participate in are high quality have also been the subject of research. Donna (2012) who conducted research on the effects of a program developed to meet the professional developmental needs of teachers developed and implemented a professional development model to improve STEM integration by using engineering design pedagogy. This model is based on the work of teachers (job-embedded), performed in the process, and promotes collaborative work. The findings of her study with 4 secondary school teachers showed that teachers gained in-depth knowledge and skills about the engineering discipline and the association of engineering with STEM disciplines. The researcher emphasized that a single professional development was not enough for teachers to develop the necessary knowledge and skills; instead, ongoing professional development experiences are required. The research conducted by Guzey and colleagues (2014) also supports the findings of this research. Guzey and colleagues (2014) examined which approaches 3-6 grade teachers used in their classes after

their participation in high-quality PD. This research was carried out in Minnesota, USA because the standards of engineering discipline were included in the teaching program and professional development was needed for teachers. Within the scope of this research, a 30-hour (5-day) face-to-face professional development workshop was organized over a year for 198 teachers of 3-6 graders from 43 different schools, and among these workshops, school-based professional learning community meetings (PLC) were held. The aim of PLCs was for teachers to reinforce what they had learned in the course and to develop a professional learning culture in their schools. A PLC facilitator was assigned to the PLC group in each school, and this facilitator guided teachers to discuss and report their practice effectively. The findings of the study showed that the teachers who participated in the professional development program successfully developed, planned, and implemented courses that included all steps of the engineering design cycle, which were correctly associated with the science curriculum. The research has highlighted the importance of high-quality professional development in the field of STEM education. Similarly, Nadelson and colleagues (2013), in order to increase the interest of primary school teachers in STEM education and to improve their competencies and self-determination, developed and implemented a 4-year development course in which teachers were provided with guidance and necessary materials, with the cooperation of researchers from the education faculty and the faculty of engineering. Researchers specifically targeted inquiry-based STEM teachers. The results of the study showed that the applied professional development course improved the proficiency and self-confidence of the teachers. Another remarkable finding of the study was that teachers' developing content knowledge had a positive effect on their STEM education practices. At the same time, the study, emphasizing the lack of STEM education in faculties that train teachers, underlines that the professional seniority of teachers has no effect on the effectiveness of their practice and therefore it is important to participate in professional development programs many times during their careers.

Studies on professional development have shown that teachers contribute to improvements in their practices. However, another important point that the researchers emphasized in common is that professional development should be spread throughout the process, and it should be perceived as an ongoing concept. If it is taken into consideration that the research on education continues after teachers start their professional life and that new findings are found, the importance of this idea will come out. Researchers have searched for the factors that enable teachers to learn effectively and studied what features should be taught when designing a

professional development course for teachers. For example, Kiebomm and colleagues (2013) studied the ways to prepare a high-quality STEM teacher and the integrated approach that teachers developed in order to combine their theoretical knowledge with practice and its effects. Researchers emphasized the importance of teachers' professional knowledge in the learning of students. They designed a model that enhanced the content knowledge, pedagogical knowledge and pedagogical content knowledge of the students enrolled in the STEM major program who wanted to become STEM teachers and the teacher candidates in their studies during the last two years of their university programs and a model that improves their skills and their contextual knowledge during the application process by working with students in the field. As a result of the study, they observed that the teacher candidates were competent enough to effectively deliver STEM content to students in more needy urban settings. The findings of the study underline the importance of process-based professional development that allows applying teachers' knowledge within the context. They also emphasize that teaching content knowledge and pedagogical knowledge alone separately did not provide effective learning for teachers, and pedagogical content knowledge and context knowledge should also be learned.

On the other hand, Donmez and Tasar (2020), by participating in the above studies, emphasized the importance of teacher qualifications in the field of STEM education and stated that not only teacher knowledge but also teacher beliefs should be improved, as teacher's beliefs filter knowledge and have an impact on teacher practices. The researcher himself/herself, as a participant, contributed to this research based on qualitative research methods. The results of the study showed that teachers' beliefs and values had a very important role in teachers' in-class practices. In addition, it was stated that the contexts of teachers were effective in their practices by suppressing their other beliefs during the application process; therefore, as well as their beliefs, the context in which they were involved had an effect.

Studies have emphasized the importance of using an effective pedagogical methods and techniques to increase student success, motivation, and interest in STEM education. Moreover, they show that teacher knowledge and beliefs in STEM education have a direct impact on teacher practices and that teachers need ongoing quality professional development in order to improve these practices. Specifically, it has been stated in many studies that teachers should have strong professional knowledge in order to apply STEM education effectively (Asghar et al., 2012; Shernoff et al., 2017).

In summary, the quality of the teachers affects the STEM education they perform and therefore the learning outcomes of the students. Research has shown that teachers' knowledge, beliefs, and practices need to be improved in order to increase their qualifications. In addition, it has been observed that these qualifications of teachers may change with qualified professional development courses (PDC). However, it is observed that it is not enough for teachers to participate in only one qualified PDC, and that teachers' knowledge, beliefs and practices are subject to development and that they should be supported with different programs during the process. When the knowledge objects that are thought to be improved in teachers are examined, it is seen that pedagogical content knowledge and context knowledge are included. It is understood from above that for effective STEM education, teachers' perceptions of STEM education, as well as PCK in STEM fields, need to be improved, and they need to be supported professionally while implementing STEM education in their own unique environment. In the next section, professional development in integrated STEM education is interpreted in terms of teacher knowledge and PCK and discussed with its general findings in the field of STEM education.

2.3.1. Teacher Knowledge and PCK

As mentioned in the first chapter, it is known that teachers need to develop different knowledge domains (content knowledge, pedagogical content knowledge (PCK), context knowledge, etc.) in STEM education. Developing these skills is through professional developments designed for teachers. This section analyzes the elements of teacher knowledge. Different types of teacher knowledge, in particular pedagogical content knowledge and its components, in STEM education and their relationship with the practice have been addressed. Additionally, teachers' role in promoting student learning in STEM education, instructional methods, techniques, and teachers' implementations are examined. In this chapter, before defining PCK in the context of STEM education, how it is defined in the literature in general is explained.

Teacher knowledge consists of many components. The first source has been described by Shulman (1987) as content knowledge that teachers possess. As Shulman (1987) described; "teachers have special responsibilities in relation to content knowledge, serving as the primary source of student understanding of subject matter" (Shulman, 1987, p. 9). However subject

matter by itself is not enough to achieve this goal (Isiksal, 2006). Historically, researchers focused on the content knowledge of the teacher to understand fundamental knowledge bases for teaching as a complex cognitive skill (Veal & MaKinster, 1999). Later researchers shifted their focus to pedagogy and teachers' classroom practices. Shulman (1987), on the other hand, advanced focusing on teacher knowledge by introducing the idea of PCK. He argues that the focusing either of the knowledge base (subject knowledge or pedagogy knowledge) results with teacher education programs put forward only one of them. To address this dichotomy, he proposed considering a new type of knowledge by introducing the notion of PCK (Mishra & Koehler, 2006). To enhance student knowledge, teachers need to "transform" content knowledge so that students can grasp the idea and develop understanding (Shulman, 1986). Therefore, he described the pedagogical content knowledge as:

> "The most regularly taught topics in one's subject area, the most useful forms of representation of those ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations – in a word, the ways of representing the subject that make it comprehensible to others. . .(I)t also includes an understanding of what makes the learning of specific topics easy or difficult: the conceptions and preconceptions that students of different ages and backgrounds bring with them to learning" (Shulman, 1986, p. 9).

While he sees the pedagogical PCK as an "amalgam of content and pedagogy that is uniquely the province of teachers" (Shulman, 1986, p. 8), he highlights that each student and so each classroom has unique characteristics of its own they bring to learning space that teachers need to consider. According to Shulman's description of PCK, a teacher must know his or her fields in such details such as analogies, representations, illustrations, examples, explanations and demonstrations, (s)he must also know how to practice them in the face of his/her current students' state of mind and the context they are in. His description also underlines the importance of knowledge of curriculum. After Shulman's (1986) seminal work in pedagogical content knowledge, many researchers in mathematics and science area/field conducted their studies, mostly relying on his theoretical framework to discover domains of teachers' professional knowledge to develop the knowledge and belief components of their frameworks (e.g., Carpenter et al., 1988; Hill et al., 2004; Howey & Grossman, 1989; Magnusson et al., 1999; Morine-Dershimer & Kent, 1999; Schoenfeld, 1998; Spike & Finkelstein, 2016).

2.3.1.1. *Teachers' Pedagogical Content Knowledge in STEM Education*

In the context of this research, teacher knowledge, beliefs and practices were the focuses regarding integrated STEM education. Therefore, to examine the characteristics of the teacher's knowledge and beliefs, the theoretical frameworks developed by researchers in the scope of integrated STEM education have been analyzed.

As it is relatively new, STEM PCK is analyzed by a limited number of researchers (Allen et al., 2016; Chan et al., 2019; Corlu, 2014; Saxton et al., 2014; Srikoom et al., 2018; Yildirim & Sahin Topalcengiz, 2019). There is not a consensus on which components should be involved in practical knowledge of teaching STEM nor how to name the theory about teachers' PCK regarding the STEM. Researchers have named their theories in these fields as STEM education pedagogy, STEM PCK, PCK for STEM, PCK for STEM, STEMPCK and integrated teaching knowledge nest egg. Regardless of how they name their theories, most of the researchers focus on the theory of STEM PCK by combining the arguments of science PCK and math PCK. Moreover, all the researchers have adopted their perspectives based on Shulman's PCK theory. Only a few studies have conceptualized STEM PCK by conducting empirical studies (e.g., Srikoom et al., 2018). Therefore, defining practical knowledge for effective STEM education seem necessary. As seen on the table, STEM components may vary from researcher to researcher. However, STEM PCK components can be analyzed under 4 categories in general which are: (1) knowledge of/related content, (2) professional development, (3) integration and (4) contextual learning. In contrast to most studies, it is aimed to base present study on empirical evidence from teachers' actual STEM lesson implementations.

The components of the STEM PCK that are contented by researchers are given in table.

Table 2.1 The Components of STEM PCK That Contented by Researchers

Components in different conceptualization of pedagogical content knowledge in STEM Education														
Model	**Researcher**													
		Knowledge of…												
		Learning and Teaching	**Student**	**Curriculum**	**Assessment**	**Pedagogical knowledge**	**Content knowledge**	**Integration knowledge**	**21st century skills**	**Context knowledge**	**Professional Development**	**Orientations toward teaching**	**Type of the study**	**Method used in the Study**
STEM education pedagogy	Sanders (2012)	C	C	N	C	N	C	C	N	C	N	N	Descriptive	Theoretical
STEM PCK	Saxton et al. (2013)	C	C	N	S	N	S	S	S	C	N	N	Descriptive	Theoretical
Integrated teaching knowledge nest egg	Corlu (2014)	C	N	N	C	N	C	N	N	N	C	N	Descriptive	Call for Papers
STEM PCK	Allen et al., (2016)	C	C	S	C	N	S	N	N	C	N	N	Descriptive	Case Study

PCK for STEM Education	Srikoom et al., (2018)	C	C	C	N	N	S	N	N	S	N	C	Evaluative	Case Study
Practical Knowledge for STEM Teaching	Chan et al., (2019)	S	C	C	C	C	N	N	N	N	N	N	Descriptive	Theoretical
STEMPCK	Yıldırım, B., & Şahin Topalcengiz, E. (2019)	S	S	N	S	C	C	C	C	C	N	N	Evaluative	Scale development

N(ull)=Not mentioned C=Component S=Subheading

The table 2.1 also hints as the types of the study. The studies utilize the literature review were named as “descriptive”. They also measure the teachers’ PCK named “evaluative”. Another distinction between the studies is their methods. Most of the studies in this field are theoretical studies. Only two of the studies are case studies, and one is measurement-scale development study. Therefore, as it is stated in the literature, relatively less effort has been directed toward defining facets of the required teacher knowledge in integrated STEM education. Consequently, more studies are required to define teacher knowledge for effective STEM education with empirical studies.

The first study which described the STEM education pedagogy was conducted by Sanders (2012). Sanders (2012) regards STEM education as technology and engineering practices integrated in science and/or mathematics education. In his research, Sanders clarified different labels of STEM education and described integrative STEM education. His description draws distinctions between integrated STEM education from using technology in effective science and mathematics education. According to him, integrated STEM education intentionally integrates the concepts and practice of technological/engineering design-based learning approaches into the concepts of science and/or mathematics education (Sanders, 2012, p. 2). Moreover, this research defines the characteristics of integrative STEM education under three subcomponents: (1) learning outcomes, (2) scope, and (3) pedagogy. Under the pedagogy segment, he focuses on consistency with learning principles, different types of designs such as interdisciplinary, transdisciplinary, and multidisciplinary, and the need for engaging students into STEM concepts and practices that provide students with a robust learning in STEM fields. Later, he reveals the principles of learning and related integrative STEM education pedagogy based on integrative STEM education literature. Mainly, he focuses on the importance of linking students’ prior knowledge with new knowledge, meaningful learning, students’ motivation, goal-directed practices coupled with targeted feedback, classrooms’ social, emotional, and intellectual climate and self-regulated learning. He states that the project-based method has been used in teaching integrative STEM subjects; however, it has been replaced with design-based instruction. His description of STEM education has been heavily cited in the literature lately. Even if this early work related to STEM pedagogy clarifies the required learning principles, it does not mention teacher knowledge in the field.

On the other hand, Saxton and colleagues (2014) based STEM pedagogical content knowledge and its components on the previous studies in the field of science PCK and mathematics PCK. They also highlighted the importance of defining pedagogical content knowledge in STEM education as it is an important outcome in all stages of teaching, and it is related to quality of teaching. Three categories were identified under the STEM PCK topic. These are: (1) teachers' knowledge of students, (2) teachers' understanding and use of effective strategies for specific STEM topics, and (3) integration of technology to enhance student learning and career and life skills. Although it is known that the definitions of effective teaching that are not based on educational practices are insufficient, with this study, effective educational practices in STEM education were structured by literature review without relying on classroom observations.

Researchers have concluded that five practices are important: (1) teachers' facilitator role, and students' active participant role, (2) deep content knowledge and higher order cognitive skills, (3) creating diverse and multiple opportunities for students, (4) using assessment for further learning, (5) contextual learning.

Given its complex characteristic and dependence on context, Saxton and colleagues, acknowledged that measuring and evaluating STEM PCK is not an easy task, nor there exists a single approach (2014). It is difficult to measure and judge the teacher's PCK. However, it may give a better idea to follow all stages of teaching with process-based measurement methods such as rubric and observation at least at two different times. Also, it is noted that aligning three components of STEM PCK in a measurement tool would give more accurate results. There has been an emphasis on professional development as an integral part of STEM education. Additionally, effectiveness of professional development is based on evaluating both PD models and teachers' classroom practices after they complete the PD courses. Notably, in-depth explanation of STEM PCK and the sources of the components of STEM PCK guided the later studies in the field and underpinned a base (See: Allen et al., 2016; Srikoom et al., 2018).

In his call for paper, Corlu (2014) called for more studies from researchers by listing the missing work in STEM education in the context of Turkey by giving a rich description of the definition of STEM education and components of potential study topics. Additionally, the researcher proposed a model for teacher knowledge in STEM education. This model is

based on Shulman (1986), Hill and colleagues (2004), his own doctoral study (2012) and his personal experience. He suggested a version of design and methodology in integrated STEM such as STEM in school programs, out-of-school time programs in K-12, professional development courses, higher education and accreditation, and methodology of scientists. Additionally, he valued quantitative and qualitative studies or mixed method studies. He highlighted the need for empiric studies in the field. He noted that these areas required further study: (1) STEM study groups, (2) contribution of STEM education to the educational policies, (3) innovative learning environments, in particular aligning innovative learning environments with current curriculum, experiences of STEM educators during implementation of integrated STEM education, inclusive learning environments and equality of opportunity in education, (4) curriculum studies, (5) teacher education, (6) STEM education in higher education. The visual representation of Corlu's integrated STEM is given below in Figure 2.1.

While his model of integrated STEM PCK is briefly explained, it is stated that this model requires empirical studies to test.

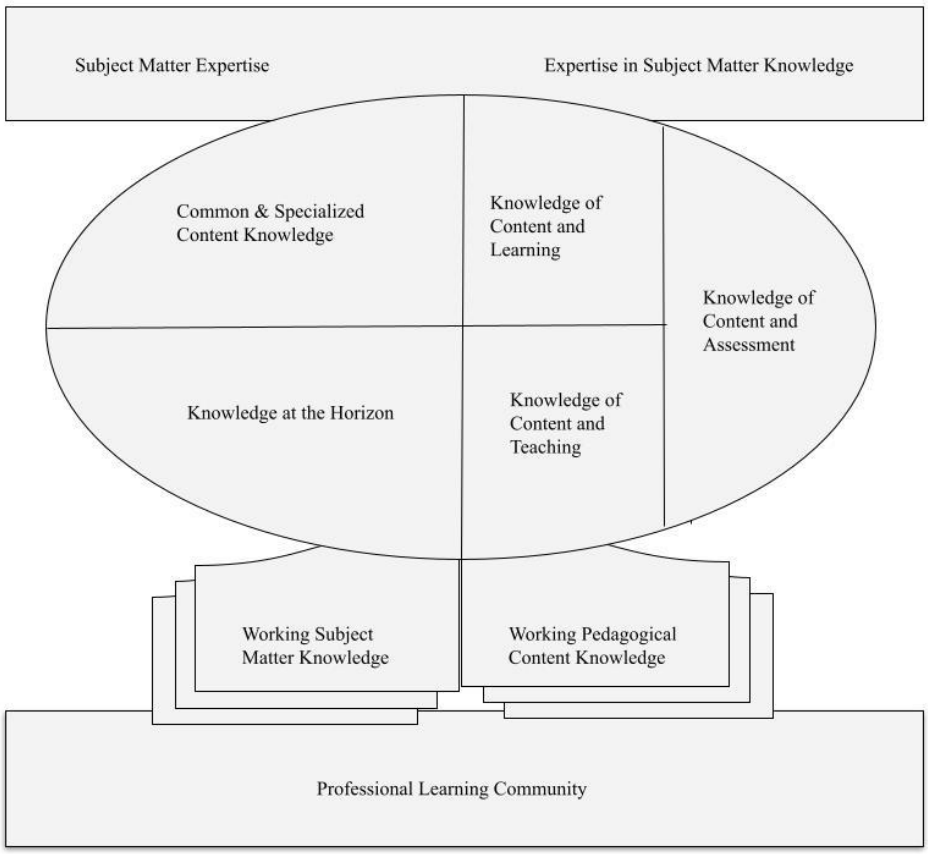

Figure 2.1 Integrated Teaching Knowledge Scheme (Corlu, 2014)

As can be seen in the Figure 2.1, two main categories are defined in the model: (1) content knowledge and (2) pedagogical content knowledge. Under the knowledge of content subhead, three categories are listed: (1) common and specialized content knowledge and (2) knowledge at the horizon and (3) working subject matter knowledge. On the other hand, three categories are listed under the pedagogical content knowledge subhead: (1) knowledge of content and learning, (2) knowledge of content and teaching, (3) knowledge of content and assessment and (4) working pedagogical content knowledge. An additional category named professional learning community has been found related to both content knowledge and pedagogical content knowledge. This model differs from others in that it defines working pedagogical content knowledge as a main component. Even if other research highlights the importance of development of teacher knowledge and professional development, none of them defines this feature as a separate category. According to Corlu (2014), STEM teachers develop knowledge which is specific to the area by sharing with colleagues. As a result of this collaboration, professional learning societies are formed in schools and cooperation has been promoted (Corlu, 2014, p. 7).

Allen and others (2016) by drawing on research and theory defined effective STEM teacher contribution named as “adaptive teaching”; then by analyzing a case of an effective pre-service teacher, they concluded the study by explaining how three components of adaptive teaching can promote students’ conceptual development, inquiry, and real-world connections. This study attracts particular attention in two ways: first, by focusing on a pre-service teachers’ experience, it highlights the importance of the change that a teacher can accomplish; second, it includes emotional attributes such as self-confidence and receptiveness to feedback, therefore differing from other studies in this regard.

Allen and others (2016) believed that three components ensure adaptive and effective STEM education. These are: (1) a well-developed STEM pedagogical content knowledge, (2) a constructivist paradigm of teaching and learning and (3) the ability to draw on a vision while reflecting during teaching to help surmount challenges in their teaching context(Allen et al., 2016, p. 218). For the purposes of this literature review, the STEM PCK component

has been profoundly analyzed. Researchers have built their conceptions of STEM PCK on a previous study conducted by Saxton and colleagues (2014). They considered STEM PCK as teachers' knowledge rather than teachers' practices. In addition, they point out that a teacher's PCK is associated with teacher quality and student learning and motivation. In their research, Allen and colleagues (2016) stated that STEM PCK consists of these three components: (1) teacher knowledge of students' thinking about STEM-related topics, (2) teacher knowledge of instructional strategies and (3) teacher knowledge of real-world STEM-related connections.

In their studies, Srikoom and colleagues (2018) emphasized the importance of students and their future by studying STEM education in an economic and political context. They stated that research in this field lacked a model and general guideline for teachers to implement STEM integration in their classrooms. They based their research on an instrumental case study. First, by analyzing current literature, PCK for STEM has been formulated. Second, after analyzing 6 cases, effective practices of teachers are identified. Third, the relationship between practice and dimensions of PCK of STEM has been examined. Their conceptualization of PCK for STEM has 5 components: (1) orientation, (2) knowledge of the learner, (3) knowledge of curriculum, (4) knowledge of assessment, (5) knowledge of instruction. They identified 4 components regarding effective STEM education practice: (1) teacher's role and instruction, (2) STEM learning context, (3) student engagement in the design process, (4) connecting to content.

Chan and colleagues (2019) proposed a theoretical framework for understanding teachers' knowledge of STEM education. Then by reviewing the literature, they identified a framework about knowledge needed for effective STEM education and proposed an interview protocol to investigate teacher knowledge in STEM education. Drawing on Allen and colleagues (2016), Magnusson and colleagues (1999) and Saxton and colleagues (2014) models about PCK of STEM education, they composed their model named "Practical Knowledge for STEM education". Their model for practical knowledge for effective STEM education has four major components. These are teacher knowledge of: (1) assessment, (2) pedagogy, (3) curricula and (4) knowledge about students. What is important here is that the boundaries between knowledge components are not explicit in practice; instead, they impact several parts of teachers' practices. It has also been vaguely stated that teachers' belief may act as a mediator between teachers' knowledge and practices.

Yıldırım and Sahin Topalcengiz (2019) proposed a model named “STEMPCK” in their research. STEMPCK is considered a combination of five dimensions: (1) content knowledge, (2) integration knowledge, (3) pedagogical knowledge, (4) 21st-century skills knowledge, and (5) context knowledge. Their conceptualization of teacher knowledge in STEM education is based on current literature in the field of each discipline in STEM education and integrated STEM education. In their studies, researchers aimed to create an easily accessible and economical tool to assess teachers’ STEMPCK. To this end, a paper and pencil test is developed for pre-service teachers. Although researchers noted that their scale might be used in both in-service and pre-service teachers, current studies show that there are significant differences between pre-service and in-service teachers’ attribution in many ways (Campbell, 1996; O'Grady et al., 2014; Teo, 2015). Therefore, their suggestion requires further investigation. On the other hand, factor analysis results have revealed that STEMPCK does not include items regarding context knowledge dimension. However, research in pedagogical content knowledge has shown that context knowledge is an indissociable feature (Breiner et al., 2012; Chan et al., 2019; Grossman, 1990). Evaluating teachers’ practical knowledge without considering their context knowledge might mislead teacher educators. As Morine-Dershimer and Kent (1999) explained in their research, context-specific pedagogical knowledge contributes directly to pedagogical content knowledge. Even though contextual knowledge is considered an important element of teachers’ professional knowledge, not all the studies have included items of this element in assessment(Kirschner et al., 2016). Nevertheless, it is important to state that readers may utilize developed tests in the research accordingly. After all, this research contributes to the PCK in the STEM education field to find different and convenient ways to evaluate the teachers’ STEM PCK. Besides, using this scale may help researchers to provide generalizable results in the future.

In summary, all the research which has developed a model for PCK in STEM education has followed different methods. However, there is cumulative knowledge stemming from all the research. The common ground for the facets of these models lies in Shulman’s study.

While some research use only literature review (Chan et al., 2019; Saxton et al., 2014; Sanders, 2012) to define PCK in STEM education, others use several methods to identify PCK in STEM education such as the case study (Allen et al., 2016; Srikoom et al., 2018), scale development (Yildirim & Sahin Topalcengiz, 2019) or the former experiences of

researcher (Corlu, 2014). In the meanwhile, Corlu's study differs from others in two ways. First, it was not a publication issued in a peer-reviewed journal, but rather it was a call for paper. Second, the aim of the paper was not to define STEM PCK as it was stated in the research; therefore, it did not give the definitions of the facets. However, given Corlu's (2014) extended research in both academia and in the field, it is found important to include this developing model. The earliest work in the field, Sanders's, was not originally written to define STEM PCK. Instead, a study describing features of integrated STEM education. Thus, we tried to define STEM PCK by using this description. This research has also been used in further PCK identification studies (Allen et al., 2016; English, 2017; Havice et al., 2018). Therefore, it is included into this literature review. Saxtons' model, on the other hand, highlighted the importance of making distinctions between conceptions of effective teaching and defining PCK. Because of their contribution to the field, these studies were also explained.

On the other hand, which subcomponents would be included in this frame depends on the definition of STEM education in the studies conducted. For this reason, the fact that the definition of STEM education covers all STEM disciplines and considers the change in the field plays an important role in defining a more valid and up-to-date STEM PCK model. For example, when the definition of STEM education in the study of Sanders (2012) was examined in the literature, it was seen that the author defined STEM education in a way that puts science and mathematics disciplines into the center, and is taught by integrating information about technology and engineering. For this reason, He concluded that the teachers should know how to integrate disciplines for effective STEM education.

The analysis of the literature review in STEM PCK showed that researchers utilized different models. The aim of the study and the methods seem to be two factors in the decision-making process. A salient difference between these models is the interconnection of several facets of teachers' knowledge such as CK, PCK, and PK. For example, two studies consider PK a main component (Chan et al., 2019; Yildirim & Sahin Topalcengiz, 2019); the others consider facets of PK as related to PCK's component. As can be seen on the Table 2.1 learning and teaching, curriculum, assessment is regarded as elements of STEM PCK in other studies (Allen et al., 2016; Corlu, 2014; Saxton et al., 2014; Srikoom et al., 2018). Regardless of the aim and method of the studies, all researchers have stated that teacher knowledge can be developed through teachers' experiences. In other words, research has

shown that teacher knowledge is not stable. For this reason, it is important to conduct research towards developing teacher knowledge. Within the scope of this research, while examining the PCKs reflecting on teachers' practices, it was aimed to be considered developmentally (Brown et al., 2013).

Moreover, just as in the mathematics PCK, science PCK and TPACK fields, it is an ongoing debate whether the orientation component (teachers' beliefs and approaches) will be examined in the context of PCK in the STEM PCK field. The literature review conducted in this section also showed that while only one study examined the orientation within the sub-component of STEM PCK (Srikoom et al., 2018), most researchers excluded it (Allen et al., 2016; Saxton et al., 2014). Srikoom (2018) defines "orientations toward STEM education " as follows: “Teachers’ knowledge and beliefs about the purposes and goals (orientations) for teaching and learning STEM: a) process, b) activity-driven, c) project-based science, d) inquiry and e) guided inquiry”. As it will be seen, according to the definition of Saxton and colleagues, the concept of orientations has been defined as beliefs about goals and objectives, and it is discussed together with teacher knowledge of STEM education. It is observed that the orientation, which they stated to be at the center of PCK for STEM, is directly related to the learner, curriculum, assessment, and instruction components. However, as they stated in their studies, further studies are needed to fully understand the relationship between these components. From this point of view, this study aims to examine teachers' knowledge, beliefs, and practices together.

When the studies on STEM PCK are examined, it is seen that they especially emphasized the lack of experimental studies in this field (Chan et al., 2019; Corlu, 2014; Yildirim & Sahin Topalcengiz, 2019). It is seen that STEM PCK frames are mostly based on theoretical knowledge in the current literature. For this reason, the need for a STEM PCK framework, especially based on teachers' practices, has been revealed in studies. In this study, a design addressing this need in the literature was carried out, and an effort was made to determine the competencies of teachers for effective STEM applications based on the practices of teachers. Researchers have stated that measuring teacher knowledge is not an easy task (Allen et al., 2016; Corlu, 2014; Sanders, 2012; Saxton et al., 2014; Srikoom et al., 2018). In order to measure teacher knowledge in the best way, it is necessary to consider teachers' practices. They have also stated that while the researchers examine the factors that affect teachers' practices, it will give more accurate results to be in a process (Morine-

Dershimer & Kent, 1999). Therefore, a study to be conducted on teachers' STEM PCKs is thought to be more comprehensive when it is in the process, and when it encompasses the examination of teachers' practices. Therefore, in this study, open-ended scales were used to measure teachers' knowledge, beliefs, and practices in the process. In this way, the goal will be to understand both the data of the STEM PCK framework to be formed from the applications in the field and the change of and reasons for the teachers' knowledge and beliefs (if any).

2.3.2. Teachers' Pedagogical Beliefs

Teachers' pedagogical belief is defined *as a holistic conception related to several dimensions, such as teaching, curricula, and the teaching profession in general* (Chen et al., 2021, p. 138). Teacher beliefs are stated as an important topic to focus as its implications may explain the educational practices (Pajares, 1992). In other words, beliefs are seen as one of the most important physiological constructions in teacher research because of their critical role in mediating teacher practices (Gencer & Cakiroglu, 2007; Khader, 2012).

Teacher beliefs play a central role in the perception of classroom situations and teachers' decision-making while addressing these situations (Wilson & Cooney, 2002). There are many studies examining the effect of teachers 'beliefs on teachers' in-class practices (Ball et al., 2001; Borko & Putnam, 1996; Stipek et al., 2001; Holt-Reynolds, 2000; Ozgun-Koca & Sen, 2011). In their study, Aguirre and Speer (1999) investigated in detail the effects of teachers' beliefs and goals on their practices in the classroom by examining the data from two teachers while teaching the Algebra lesson. The findings of this study, which was carried out using a case study, have shown that teachers' belief systems in teaching mathematics affect the goals of teachers and the decisions they make in the teaching process. In addition, the research has revealed findings as to which beliefs play a role in determining which goals and how this reflects on their teaching when examining their teaching episodes. The study has revealed that teachers' beliefs play an important role in their educational decisions. In another recent study, Bray (2011) investigated the effect of teacher beliefs on teachers' in-class practices by examining error-handling practices in mathematics lessons along with other variables and obtained more detailed information. Bray (2011) investigated the error-handling practices of 4 3rd grade teachers in mathematics lessons and researched the effect of teachers' beliefs and knowledge on their teaching. The findings of Bray's research have

shown that teachers' beliefs and knowledge both influence the way teachers handle errors during teaching, but their beliefs more often determine the way they structure their classroom discussions, as well as the roles they assign to themselves and their students.

2.3.2.1. *Exploring Teachers' Pedagogical Beliefs and Process of Change*

Professional development courses are seen as the most important tool for teachers to understand, develop and support their beliefs in their effects on their teaching. The nature of teachers' beliefs that should be considered by professional development mentors have been identified as follows: "Beliefs are formed throughout teachers' lives, schooling and careers" (Van den Bergh et al., 2014, p.421). In addition, beliefs are complex and personal (Nespor, 1987). Consequently, beliefs may change only if they are challenged (Pajares, 1992; Raths, 2001).

Although professional development courses are an effective way for teachers to develop new beliefs and to reflect effective beliefs in learning onto teachers' practices, there have been two distinct approaches identifying change in teacher beliefs. The first approach posits that changing teachers' belief is difficult since they have developed over years (Kagan, 1992; Pajares, 1992; Philipp, 2007). For example, in a study wherein teacher candidates analyzed video evidence of their practices to identify their beliefs and actions, meetings and peer reviews would facilitate change in teacher candidates' belief only after several weeks of video analysis. The results of the research have shown the difficulty of changing teachers' beliefs (Bryan & Recesso, 2006). The second approach claimed that teachers' beliefs could change significantly even in a week-long training. For instance, Fitzgerald and Cunningham (2013) found that elementary teachers' attitudes toward and beliefs about teaching engineering changed significantly over the course of a week-long training. Similarly, Rich and colleagues (2017) revealed that teachers altered their beliefs about the importance of computing and engineering. In addition, Guskey's statement supports this view. He (2002) argues that change in teachers' beliefs occurs after changes in students' learning are evident. Most significantly, beliefs are unlikely to change unless they are challenged (Pajares, 1992; Raths, 2001). However, a recent study has revealed a new finding apart from these two views. In his work with teachers who are both experienced and new to the profession, Luft (2001) saw that although new teachers are more prone to change their beliefs, they are less likely to change their practices. Experienced teachers, on the other hand, are less likely to change their beliefs, but more likely to change their practices.

The findings of these studies on the change in teachers' beliefs carry important clues for the professional development courses to be developed to be more effective. In the light of these studies regarding the change in teachers' beliefs, for any professional development program to be successful, it is important to consider nature of beliefs and facilitate teachers to build new knowledge on their own practices, knowledge, and beliefs (Verloop et al., 2001).

Current literature about the beliefs of teachers in STEM education focuses on the teachers' beliefs, teachers' perceptions about STEM education, in-class practices and the relationship between them (Wang et al., 2011), teachers' beliefs, attitudes and content knowledge about STEM education (Shahali et al., 2015), teachers' perceptions and beliefs about the use of integrated STEM curriculum in science teaching (Acikgul Firat, 2020), teachers' beliefs and practices in STEM education (Wang et al., 2020), teacher candidates' intentions and beliefs about STEM education (Kurup et al., 2019), teachers' beliefs about STEAM education (Jamil et al., 2018) and the effect of teachers' beliefs about 3D printing integration on students' STEM motivation in science classes (Cheng et al., 2020). It is seen that while many researchers examine teachers' beliefs, perceptions and attitudes towards STEM education (Acikgul Firat, 2020; Kurup et al., 2019; Jamil et al., 2018), a limited body of research studies focused the relationship between teachers beliefs and their practices (Wang et al., 2011; Wang et al., 2020) and again a limited number of studies have examined the relationship between belief and teacher knowledge (Shahali et al., 2015). Researchers have highlighted that studying teachers' beliefs and knowledge in relation to teaching is essential in developing more effective teaching and to make recommendations for future research.

A study conducted in Turkey has described the perceptions and beliefs of the teachers on STEM education in Turkey. The study conducted by Acikgul Fırat (2020) showed that with STEM education, teachers' professional development would change positively and that students would improve their academic success in lessons, create an original product, be pushed to thinking and using their knowledge in daily life and contribute to their personal development and personal development. However, the study found another striking finding about perceptions of teachers in Turkey; teachers do not know about the STEM concept. The research has emphasized that there are more important issues while discussing the competence of teachers in STEM education all around the world. In addition, this study

suggested that future studies examine teachers' practices, beliefs, and knowledge by observing their in-class practices. Because there is no curriculum yet in Turkey, he stated that teachers' beliefs and knowledge were also analyzed with the data collected through interviews. Research findings discussed above show that when the comparative results of the investigations carried out in the world and Turkey are examined, research contexts affect results obtained from study. As a matter of fact, researchers have insistently pointed out that beliefs should be considered in the context (Ertmer, 2005; Norris et al., 2003; Liu, 2011). Tobin (2015) highlighted those beliefs have important role in achieving someone's goal and *"this can be undertaken only in social milieu"* (p.5). Several factors are seen as facilitators or deterrents during a teacher's transition of beliefs into practice such as a teacher's personal science background, peers, teachers, personal traits (Palmeri & Nosofsky, 1995). Therefore, context, socio-cultural and institutional factors are determinants in the implementation of teachers' beliefs into their practices (Roth & Roychoundhury, 1994). For instance, research can be interpreted as in the case of Turkey one deeply embedded cultural belief is that math and science achievement depend on native aptitude and ability whereas in other countries, such as Japan, mathematics and science achievement is believed to come from effort (Clements & Sarama, 2016). Besides, mathematics and science subjects are considered difficult by students, and it is determined that the reason behind this belief is teachers' behavior and teaching approaches (Bekdemir, 2010; Yenilmez et al., 2007). Therefore, discovering and developing teachers' beliefs in their context seem crucial in student learning.

2.3.2.2. ***Teacher Beliefs Frameworks***

The examination of different frameworks and classification of teacher beliefs provide evidence of a variety of subcomponents of teacher beliefs. Both theoretical and experimental research seems to enable researchers to make classification of teacher beliefs. Belief frameworks are useful to understand teachers' beliefs and actions, and to improve professional development for teachers. Researchers in the STEM field have distinguished several belief facets (Calderhead, 1996; Ernest, 1989; Schoenfeld, 1998; Spike & Finkelstein, 2013; Thompson, 1992).

Ernest (1989)described teachers' belief about mathematics in three subcomponents. These are (1) student learning, (2) classroom instruction, and (3) nature of mathematics. Further, Ernest stated that teachers' beliefs about the nature of mathematics fell under three common belief structures: (a) problem solving—mathematics as a dynamic and continually

changing field of study; (b) Platonist—mathematics as a static, yet interconnected, body of knowledge; and (c) instrumentalist—mathematics as a useful collection of rules, procedures, and algorithms. Thompson (1992) stated that two facets of teacher beliefs were distinguished, first, epistemological beliefs about the nature of mathematics, and beliefs about the teaching and learning of mathematics. Both types consist of a more traditional dimension and more process-oriented dimensions.

Calderhead (1996) on the other hand, hypothesized that there were 5 subcomponents of teachers' beliefs. These are teachers' beliefs about (1) subject matter, (2) learner, (3) learning, (4) teaching and (5) the role of the teacher.

In his theory of 'Teaching in Context' study wherein Schoenfeld (1998) examined how and why teachers made specific decisions and took specific actions while they taught describes teacher beliefs along with goals and knowledge from a holistic point of view. He has stated that which goals or action plans are chosen by the teacher in each time and particular context is determined by teachers' beliefs, consciously or unconsciously. Before he introduces relevant classes of beliefs for his model, he highlights two points from literature: first, the effects of beliefs on behavior and second, the difference between professed and attributed beliefs. He categorized teacher beliefs into four subcomponents (Schoenfeld, 1998, p. 3).

1. Beliefs about the nature of subject matter,

2. Beliefs about the nature of the learning process

3. Beliefs about the nature of the teaching process and the roles of various kinds of instruction

4. Beliefs about particular students and classes of students.

Furthermore, he asserts that beliefs are often context dependent. In different contexts they tend to be activated in clusters and conflicting beliefs can compete for priorities.

In their case study which focuses on the impact of teaching experience and preparation on the pedagogical beliefs of physics teaching assistants (TAs), Spike and Finkelstein (2010), they focused on the patterns between two TAs with pre- and post-interviews. They

determined three types of professed beliefs that TAs hold: beliefs about teaching, beliefs about learning and beliefs about subjects. Researchers' follow-up study focused on teachers' beliefs about teaching (2013). With extend data collection tools (interview protocol, video recordings of teaching, observation protocol) they analyzed connections between teaching assistants' beliefs and practices and developed a framework. Three dimensions of teacher beliefs about teaching have been identified after analysis of data: (1) agency, (2) goal of instruction, (3) assessment.

In this study, the beliefs of teachers in STEM education are examined. The research findings mentioned earlier in this section are taken into consideration. A professional development program that will support teachers' beliefs and practices and based on their practices was developed and implemented in the context of Turkish education system. Moreover, it was aimed to examine the relationship between teachers' beliefs, knowledge, and practices by examining their practices with multiple data sources. Considering the teacher belief frameworks stated in the literature and examining the data obtained, the framework of teacher beliefs in STEM education has been established. Teacher beliefs were categorized by adapting the broad belief categories from Schoenfeld (1998) and subcategories are drawn from Raymond (1997) and Aguirre and Speer (1999). As a result, teacher beliefs, categories, and the data they represent in STEM education are explained in detail in the results section.

In summary, teachers 'beliefs play an important part in teachers' in-class practices, in the roles they assign to themselves and their students in the teaching process, and in the implementation of lesson plans (Ball et al., 2001; Borko & Putnam, 1996; Holt-Reynolds, 2000; Wilson & Cooney, 2002; Ozgun-Koca & Sen, 2011; Stipek et al., 2001). In fact, research has shown that the practices in the classroom of teachers who have the same information, but different teaching beliefs also are shaped in line with their beliefs(Ernest, 1989). In addition, teachers' beliefs affect the success of their students (Goddard et al., 2004; Ozgun-Koca & Sen, 2011; Ross et al., 2001). Teachers' beliefs are based on their past experiences, family experiences, socio-cultural contexts, and professional development courses they attended (Ertmer, 2005; Lumpe & Chambers, 1997; Furinghetti & Pehkonen, 2002; Rich et al., 2017).

To systematically examine teachers' beliefs and the resulting frames provides important clues to examine teachers' instructional decisions and their reasons in their classrooms. It is also thought that it will help to determine a road map for the professional development courses to be developed (Calderhead, 1996; Ernest, 1989; Schoenfeld, 1998; Spike & Finkelstein, 2013; Thompson, 1992).

2.3.3. Professional Development

Countries take different initiatives regarding STEM education. In Turkey, for instance, it is observed that there is no direct STEM education plan prepared by the Ministry of National Education, but goals are set to strengthen STEM education (Kose, 2020; MoNE, 2015). In 2005, by the Board of Education and Discipline, the primary school education plans for 1-5 classes were renewed by adopting the principles of the constructivist approach and were put into practice in the 2005-2006 academic year. Thus, it was emphasized that Science and Mathematics lessons should be free from memorization, should be in life and usable (MoNE, 2005, as cited in Celenet al., 2011). Examination of the Ministry of National Education on STEM education shows that a project or research plan titled "Science, Engineering and Entrepreneurship Practices" was added to the end of the unit in the teaching plans, and in 2019, a guidebook titled "STEM Education Teacher's Handbook" was prepared for elementary teachers. Yet, teachers' knowledge and experiences play a decisive role in its implementation. Gul Ozbilen (2018) studied teachers' views and awareness about STEM education and found that teachers saw themselves inadequate in STEM applications, but they had difficulties in receiving education about the STEM model, and most of the teachers were not informed about training and even so, they could not attend the trainings they were informed of due to the lack of quota. In addition, it was observed that teachers who are informed of STEM education do not want to improve themselves in this field because they do not believe in its disposability in the existing education system. The findings of the research underline the fact that, in the context of Turkey, integrated STEM education has made decisive emphasis on the teacher's role. On the other hand, Yildirim (2018) studied the opinions of teachers who applied STEM education in their lessons regarding STEM education. The findings of this study also show that teachers do not feel themselves competent in STEM content knowledge. In addition, this study reveals that teachers do not have sufficient knowledge and practicum, especially in engineering and technology education. The research also reveals the need for a well-prepared teaching program. In the

research of Hacioglu and Baspinar (2020), student and teacher opinions regarding the implementation of STEM education activity plans prepared by field experts based on the needs stated by Yildirim are examined. This research differs from other studies in that field experts' mentor the teacher who performs the application. The findings of the study, like other studies, indicate that teachers feel insufficient in terms of time management and pedagogical content knowledge. However, in addition to this, it has also revealed that it can be applied in schools when appropriate learning environments are prepared, and teachers are mentored. Analysis of the research findings show that teacher qualifications have an important place in the implementation of STEM education, and to improve teacher qualifications, it is necessary to improve the professional development of teachers and support them during innovative practices.

The reform movements in STEM education emphasize constructivist and inquiry-based teaching practices (Capps & Crawford, 2013; Marshall et al., 2009; McNew-Birren & van den Kieboom, 2017). Among the objectives of education reform is the realization of education that enables students to learn by associating with their prior knowledge, based on their own experiences and by questioning. This teaching model is seen as a profound change for many teachers because they know that they have been subjected to traditional teaching in their education process, and the principles of traditional education also conflict with the ones that the constructivist approach has. Additionally, although STEM education at primary school level generally prioritizes science and mathematics, historically, technology and engineering have been more in the background. For this reason, many elementary teachers who are currently working have not been involved in an education related to technology and engineering disciplines, even though they study in science and mathematics and received training in the teaching of these disciplines at education faculties. Professional development courses are seen as an effective way to improve teachers' knowledge and skills in STEM fields. In order to better understand the place of professional development in STEM education, it is necessary to understand how it is defined and how it will be effective.

Guskey (2000) describes teacher professional development as "ongoing, intentional, and systematic educational training opportunities that are made available to educators in their schools and districts". Professional development is also defined as a process which leads to a change in teachers' knowledge, beliefs and attitudes but also leads teachers to acquire new skills, concepts and processes related to instruction (Fishman et al., 2003). Professional

development is considered as experiences that provide student learning in a positive manner with the application of knowledge, understanding and skills and improvement in teachers' instructional practices aligned with the goals of the school district or individual school or the educators' personal professional goals over a period of time (Darling-Hammond & Richardson, 2009).

Professional development is seen as a key element for student learning and success of standards-based educational reforms by many researchers and policymakers (Borko, 2004; Fullan et al., 2006; Nye et al., 2004; Rhoton & Stiles, 2002). Researchers also indicate that the one of main reasons for conducting professional development is to enhance student achievement (Guskey, 2003; Reeves, 2010). It has been identified that there is a positive relationship between the extent of teachers' participation in professional development and quality of the instructions and their observed lessons (Banilower et al., 2006; Heck et al., 2006; Supovitz & Turner, 2000), thus, there is a connection between professional development and teachers' classroom practices.

Although professional development is considered as an essential training for making educational reforms introduced by supporting teacher growth and organizational change (Borko et al., 2002), it may require years of effective professional development for teachers to change their classroom practices (Lappan et al., 1988). Nonetheless, professional development programs have been referred to as a requirement for teachers' growth, and integration of reform-based instructions in their classrooms over time (Jong et al., 2010). Professional development promotes teachers' decision-making process through experiences during the programs (Graham & Fennell, 2001) and enables teachers to improve instructions (Sparks & Hirsh, 2000).

According to research about teacher qualifications associated with the type of teaching advocated by standards-based reform, Desimone and associates have determined that professional development could increase reform-oriented teaching strategies among teachers at different length of experience and qualifications (Porter et al., 2000). Although there are many forms of PD, Gulamhussein (2013, pp. 14-18) has identified the key principles of effective professional development activities. These principles guide educators to create successful and meaningful PD programs:

1. Professional development experiences must allow time for teachers to learn, implement and master new teaching strategies

2. Teachers need to receive support during the implementation stage that addresses the challenges of changing teachers' implementation

3. PD experiences must enable teachers to be active participants by engaging in varied approaches so they can become competent in new practices

4. PD provides opportunities to see the action and conceptualize the new concept rather than just hearing about it; therefore, modeling should be involved in PD

5. The content of professional learning must be specific to the discipline for middle and high school teachers or must be specific to the grade-level for elementary school teachers.

To recap, after years of experience with teachers, Putnam and Borko (2000) suggested a promising model which is based on systematically incorporating multiple contexts. In this model, PD starts with introducing theoretical and research-based ideas and continues with on-going support during the school year (Franke et al., 1988) and teachers are allowed to practice and reflect on their own teaching. As teachers attempt to integrate the theoretical ideas into their own classroom practice, they are provided feedback, demonstrated lessons, and given opportunities for reflection during the visits to the teachers' individual classrooms and additional workshops for exploring issues as they emerge. In this respect, this model was used in the current study to help teachers grasp the conceptualization about integrated STEM education, develop an understanding of the characteristics of integrated STEM education and improve their skills while they received feedback and reflected on their own teaching.

3. METHODOLOGY

Methodology is a systematic approach to research in order to investigate the social world. Specifically, Schwandt (2014) explains that methodology is a model to be followed, assumes, and guides general methods and procedural details in the fields. According to Mills and Birks (2014), methodology determines how the researcher considers a study, the process of making decisions about a study and how they position themselves to engage with participants and with the data collected. They have explained the components of methodology as choice and recruitment of participants, data generation and collection, fieldwork, data recording, data analysis and data reporting of the study.

This chapter includes a description of the chosen research method and design, the rationale of the research design, and how the design of the study facilitated the procedures to select participants and choose appropriate methods of the data collection, processing and analysis, methodological assumptions, limitations and delimitations and the ethical considerations to investigate the research questions.

3.1. Design of the Study

The design of the research can be selected according to the types of the research questions, the role of the researcher and the focus of the study (Yin, 2003a). In this case study, the aim was to investigate and examine elementary school teachers' pedagogical content knowledge and beliefs during the participation in professional development course, and the qualitative research approach was used. In three classrooms, it is examined in what ways teachers' beliefs and pedagogical content knowledge took part, the relationship between these, as well as the contribution of professional development courses to teachers and conclusions about implementing integrated STEM education in public schools.

It is particularly useful to employ qualitative research approach when there is a need to obtain an in-depth appreciation of an issue or phenomenon in its natural real-life context (Crowe et al., 2011). Similar to them, Baxter and Jack (2008) describe qualitative case study as "an approach to research that facilitates the exploration of a phenomenon within its context using a variety of data sources" (Baxter & Jack, 2008, p. 544). Qualitative research strategies guiding this study aim to explore an in-depth, multi-faced understanding of the teachers' pedagogical content knowledge and beliefs in integrated STEM education. Case

study, as a study approach, enables the study to achieve these ends since it was suitable for the purpose of the research.

According to Creswell, case study is a qualitative approach that is defined by four characteristics: (1) researcher investigates a case or cases over time in detail, (2) rich data collection is involved where multiple resources of information are utilized, such as observation, interviews, and audio-visual material documents and (3) it presents the description of case or cases (2007). Case study method enables researchers to focus on data within a specific context and analyze in detail (Stake,1995; Zainal, 2007). In other words, case study is an empirical inquiry that investigates a contemporary phenomenon within its real-life context, when the boundaries between phenomenon and context are not clearly evident, and in which multiple sources of evidence are used (Yin, 2014, p. 24). Merriam (1998) has stated that case study is "an intensive, holistic description and analysis of a bounded phenomenon such as a program, an institution, a person, a process, or a social unit" (Merriam, 1998, p. 27). The case, then, is defined as "in effect, your unit of analysis" (Miles & Huberman, 1994, p. 25). Similarly, Merriam has emphasized that the unit of analysis characterizes a case study, not the topic of investigation (Merriam, 2002). On the other hand, people's behavior in "well practiced" domains as it can be seen in this research, "teaching" in particular, can be understood as a function of their knowledge and sources, goals, and beliefs and orientations (Schoenfeld, 2011, p. 457). The aim in the present study is to investigate how elementary school teachers' pedagogical knowledge and beliefs are reflected in their practices, to understand how they ascribe meaning to the experiences and practices within the context and to examine the development of their pedagogical knowledge and beliefs during the process. Therefore, one public elementary school (a bounded system) was selected in the current study because it was typical (Merriam, 2002).

This research sought to understand teachers' cognitions (beliefs and pedagogical content knowledge) as in their in-class practices throughout their participation of a professional development course that occur in a complex environment, such as an urban elementary school. Thus, an instrumental case study was selected as a methodological approach that allowed researcher to analyze teachers' applications and cognitions in-depth. Stake (2003) defines instrumental case study which is "examined mainly to provide insight into an issue or to redraw a generalization" (p. 137). Stake distinguishes instrumental case study from intrinsic case study by stating: "for intrinsic case study, case is dominant, the case is of

highest importance because the case presents an unusual or unique situation; for instrumental case study, issue is dominant; we start and end with issues dominant (Creswell et al., 2007; Stake, 1995, p. 16). Our study is an instrumental case study involving a group of individuals who experienced a phenomenon. According to Stake (2005), an instrumental case study allows researchers to gain an insider's view. Instrumental case study design was selected because aim of the study was to investigate nature of teachers' cognitions and practices and development throughout a professional development program in STEM education. Purposive sampling method that has been used is explained. In instrumental case study researcher selects a small group of subjects since it allows to examine a certain pattern of behavior (Zainal, 2007). Extensive data collection is made based on multiple sources such as interview, observation, documents, and video recordings of lessons. Detailed description of each case is provided through holistic or embedded analysis of the data (Yin, 2009). Additionally, cross-case analysis is conducted to evaluate current theoretical propositions about the phenomenon (Stake, 2013; Yin, 2003). A case study will allow the researcher to analyze within each setting and across settings. The application of a conceptual framework is considered an important component in the designing and implementing process of a rigorous case study (Baxter & Jack, 2008). Therefore, initial propositions concerning variables in the conceptual model are created based on an extended literature review. Teachers' beliefs in STEM education and STEM pedagogical content knowledge and their developments and roles in decision-making in the implementation of integrated STEM modules are utilized as a conceptual framework. The theoretical propositions guided the collection of data and finalized propositions have been discussed in the conclusion section (Stubbs & Myers, 2015).

Stake has pointed out five steps of research design in case study implementation (Merriam, 1998; Yazan, 2015). Case study design begins with conducting literature review. At the second phase, constructing a theoretical framework is required. In addition to Stake's research design steps, Miles and Huberman (1994) emphasize the importance of providing a model of a conceptual framework. These authors have stated that the conceptual framework has a critical role in three purposes in case study research: (1) identifying the participants of the research, (2) describing what relationships may be presented based on theory; and (3) providing the researcher with the opportunity to gather general constructions into intellectual "bins" (Miles & Huberman, 1994, p. 18). Research problems are identified in the third phase.

In the fourth phase, researchers craft and sharpen research questions. Lastly, sample selection is put into action. In this research, this five-step approach has been adopted and implemented to disclose detailed and meaningful understanding of the case.

Using Stake's (2003) instrumental case study approach, this study merged conceptual ideas with qualitative data to create an inductive inquiry on teacher voice and application. Using a qualitative study with a case study design gives voice to the participants who have experience with the phenomenon (Charmaz, 2006; Glaser & Strauss, 1967; Stone & Perumean-Chaney, 2011). Case study is an appropriate approach for providing a vast description of the cases as well as bringing about the discovery of a new meaning; therefore, case studies, have been utilized considering its in-depth description of the elementary school teachers' engagement in professional development course and integrated STEM module implementations (Merriam, 1998).

3.2. **Participants**

Sampling is a critical aspect in the research process since it maintains the quality of the data, interpretation, and underlying findings (Collins et al., 2006). In both quantitative and qualitative studies, researchers must determine both the course of sample member selection and the number of participants (Onwuegbuzie & Collins, 2007). The current study structured as a qualitative case study, accordingly, seeks to "understand phenomena in a real world setting where researcher does not attempt to manipulate phenomenon of interest" (Patton, 2002, p. 39). Qualitative research, unlike quantitative research, aims to illuminate, understand, and extrapolate similar situations (Hoepfl, 1997). This study examined elementary school teachers' perceptions and experiences on implementing integrated curriculum and the conceptions that teachers developed throughout the professional development related to pedagogical principles and beliefs in STEM integration. Therefore, a purposeful sampling strategy was used in the current study to identify and select participants who provided thick, rich, and in-depth experiences with integrated STEM curriculum which allows researchers to conduct information-rich cases (Patton, 2002). Three elementary teachers participated in the present study from beginning to the end. All the teachers were female and had graduated from the department of elementary teacher education. The real names of the elementary teachers were not used in this study; instead, pseudonyms were given as Merve, Naz, Zeynep.

In a case study, participants need to be chosen carefully. Consequently, three concepts were considered while selecting participants: first, the present study seeks to understand teachers' practices regarding their PCK and beliefs throughout a professional development course and lesson implementations; therefore, chosen participants needed to devote a long period of time to participation. On the other hand, professional development courses were structured in such a way that collaborative learning would take place and teachers would discover and share their own experiences. Before the study, teachers were informed about the process of the study and professional development courses. Participants were selected from among those who were willing to allocate a long period of time and develop themselves in the professional field. Secondly, several data collection methods were included in this research such as interviews, video records, audio records, lesson planning and mathematical and science identity autobiography documents. Therefore, teachers who attended this study needed to have low levels of self-concerns. Additionally, teachers' prior knowledge would be sufficient to create integrated STEM modules and evaluate the process. According to Marso and Pigge (1994), teachers who are in their mid-career levels' teachers deal successfully with their self-concerns. For this reason, teachers who had completed their first 5 years in the profession were selected. Thirdly, to conduct a fair cross-case analysis of teachers' pedagogical content knowledge and beliefs, teachers' student population should represent general diversity in Istanbul (including socio-economic, ethnic, academic, and behavioral and language diversity). As a result, participants were selected from the same school that has a similar student population in their classrooms.

I initially gained access to each elementary school principals based on previous contacts. I spoke with potential cases about the nature of the study and the time required for the investigation. Of the six schools contacted, one principle was willing to cooperate. Once the principle agreed to participate in the study, I followed up with the elementary teachers to present the purpose, process, and timeline of the study. Six teachers were interested in participating in the study; however, one teacher quitted since the time frame overlapped with his after-school courses and two teachers were in the first year of their profession. Therefore, they were not meeting the criteria. As a result of aforementioned concerns, willing to collaborate throughout the professional development course as well as create, implement and reflect integrated STEM modules, three public elementary school teachers participated in this study. Once the teachers agreed to participate in the study, the agenda of the professional

development course was shared, with the support from the principal. The course location was decided on. A camera and a voice recorder were planted.

Next, the researcher presented additional information about the participants including their educational backgrounds, their former math and science learning experiences and professional development courses they had attended and their work experience to provide deep context for the study.

Table 3.1 Participant Teachers' Educational Background

Participants' Names	**Graduation Year**	**Academic Degree**	**Graduate School**
Merve	2004	B.S. Elementary Education Trakya University	-
Naz	2006	B.S. Elementary Education Atatürk University	M.Ed.Yeditepe University
Zeynep	2001	B.S. Elementary Education Marmara University	-

As reflected in Table 3.2.1, all the researchers had graduated from public universities. All participants were in the middle stage of their careers. The participants had similar educational backgrounds with degrees from elementary school education except for the fact that one of the participants held a graduated degree from a private university with a master's program in educational Administration and Supervision Non-Thesis degree and Merve applied to graduate school at the end of the study.

Table 3.2 Participant Teachers' Former Teaching Experiences

Participants' Names	Year of Teaching	Former Experiences
Merve	14 years	In a suburban elementary school- 1 year Şehit Askeri Çoban Primary School - 13 years

Naz	11 years	Ankara- 5 months paid teacher Ankara Seyh Samil Primary School – 5 years Şehit Askeri Çoban Primary School 5 years
Zeynep	17 years	Mardin Kızıltepe- Vatan Primary School - 2 years Şehit Askeri Çoban Primary School- 15 years

As reflected in Table 3.2.2, all the teachers have between 10 to 20 years of experience in the field. And all the teachers have at least 5 years of experience in the research school. All the three teachers only worked in public schools. Two of the researchers have suburban public-school experience, and one of the teachers has only urban public-school experience. One of the teachers worked in the Eastern part of Turkey. And one of the teachers worked in the northeastern part of Turkey. Naz was teaching only in urban areas. All the teachers started work as an elementary school teacher right after they graduated from college.

3.3. **School Setting**

The primary school in which professional development and lesson implementations were carried out with the help of the cooperating teachers and administration is one of the public schools situated in the northern part of Turkey. The county which the research school is in has a population of approximately 22.896 and represents a wide variety of backgrounds, educational levels, and economic conditions. On average, the population is largely low class and most of the parents' higher education level is middle school. The school is the only primary school in the school district with a total student population of approximately 1400 and has 44 classes, 60 teachers and 4 principals.

The school is a public school which has three buildings. The first-grade classes and kindergarten have their own buildings and the rest of the classes (2-4) are in another building. The school has three schoolyards; the biggest schoolyard is in front of the school and paved with asphalt. The second one is on the right side of the school and this schoolyard was used for gardening by teachers for a project three years ago. Since then, it hasn't been used at all. And the third garden is only used by kindergarten students as a playground.

The school is a traditional, discipline-based school and all teachers use the curriculum supplied by the government coming with a set of books (teacher's books, textbook, and workbook). Teachers are expected to have a class starting from 1st grade and teach the same class through 4th grade. Additionally, teachers are expected to teach each module in a given time. Also, each class has an official notebook on which teachers need to write which standards are taught in each lesson. Each day, elementary teachers are expected to receive official confirmation from the school principal. All elementary teachers have multiple subject credentials without "Foreign Language: English" credentials. Of all the attendees, two of the teachers were teaching 2nd grade, and one of the teachers was teaching 3rd grade.

Officially, all classes have 6 hours of lessons and 5 breaks. Each break is 10 minutes long, and each class is 40 minutes long. In 2nd grade's official weekly schedule has 5 hours of mathematics lessons. Social sciences and science lessons are taught under the name of 'life sciences' lessons and there are 4 hours of life sciences classes each week. In the 3rd grade, the official weekly schedule has 5 hours mathematics classes and 3 hours science classes. There is no technology or information technologies and software classes in the weekly schedule (e.g., Appendix 1). Teachers teach their integrated STEM modules in both mathematics and science (in the 2nd grades life science) lessons. In this school, there is no science laboratory or computer laboratory. Teachers have physical education lessons in the schoolyard according to a weekly schedule prepared by the school administration.

3.4. **Procedure of the Study**

The purpose of this research was to investigate elementary school teachers' beliefs and pedagogical content knowledge during a professional development course and their teaching practices. A summary of the sequence of research procedure can be found in the following timeline (see figure 3.1).

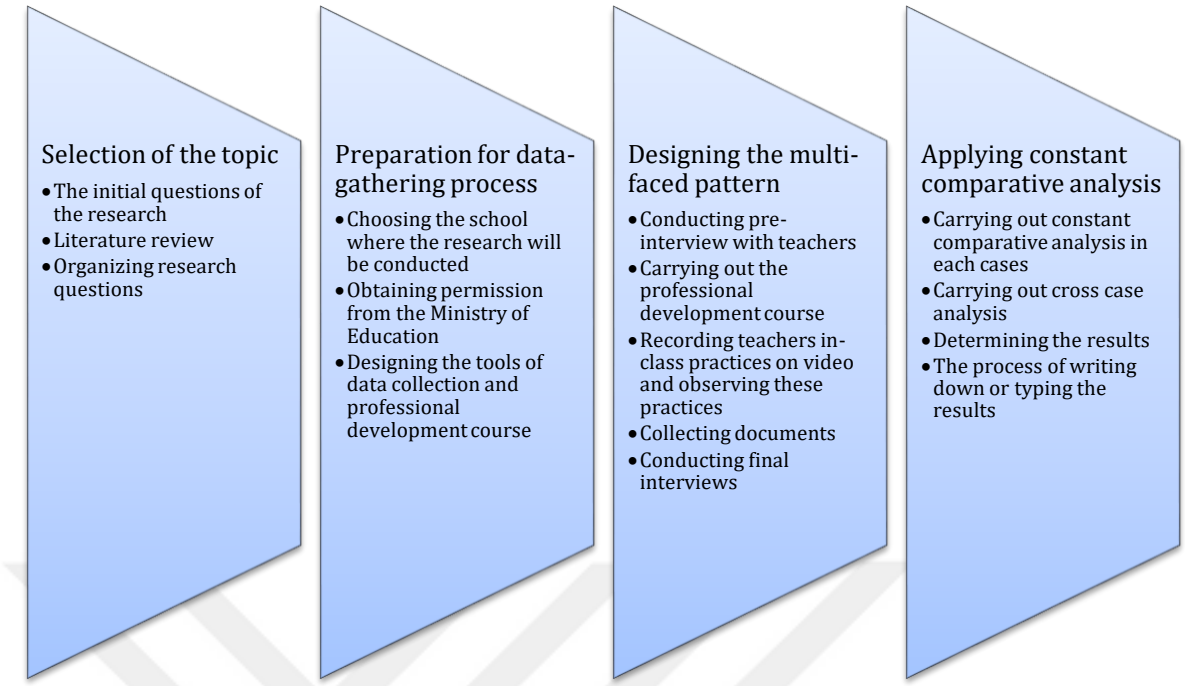

Figure 3.1 Research procedure

The learning and teaching strategies that have been used in the professional development course aimed to facilitate learning and stimulate teachers to alter educational practices including small group discussions, use of videos to examine central aspects of learning and instruction (Borko et al., 2011), elaborating and reflecting on teachers' own experiences with the tools such as mathematics and science autobiography (Willey and Livers, 2018), working collaboratively during the course (Avalos, 2011).

The professional development program consists of a vocational development course and subsequently the work of teachers to develop, practice and improve STEM modules. The process of the professional development course is explained in the image below (See figure 3.2).

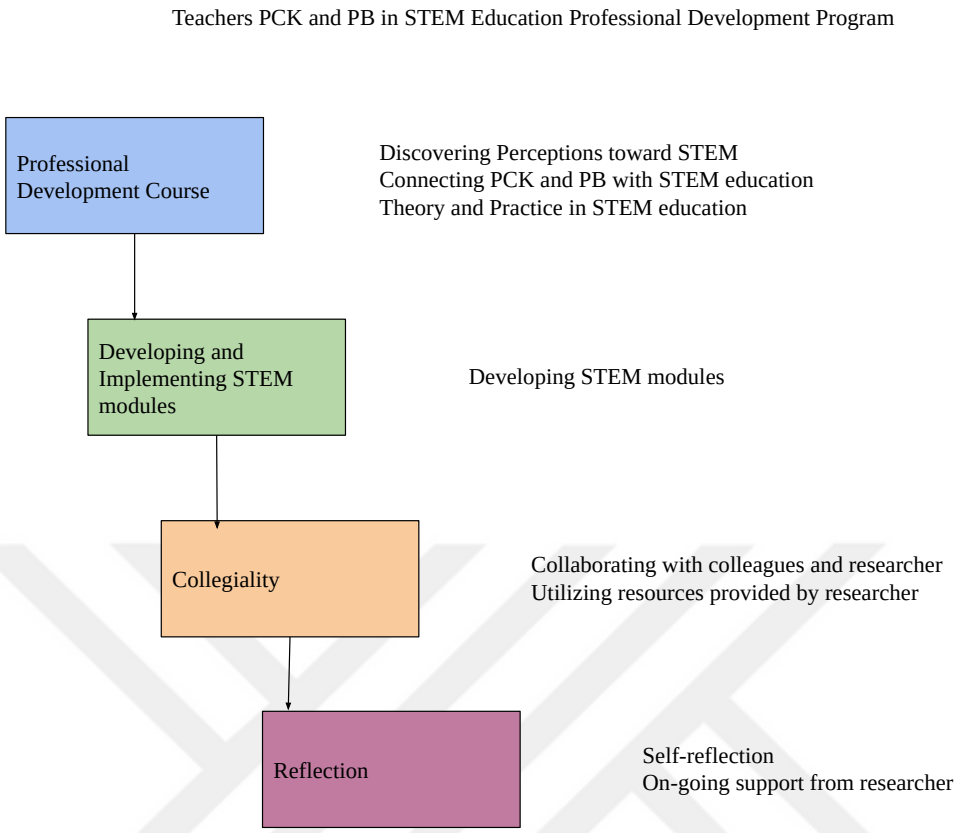

Figure 3.2 Professional Development Program

Having completed the professional development course after two weeks, the teachers developed their integrated STEM modules. In the development process of lesson plan, the teachers worked collaboratively at the beginning as a part of the professional development course. The teachers discussed which concepts and standards to include in the lesson plans, how to implement them, and what assessment tools to use. Audio recordings from these sessions provided insights into how teachers made their decisions on the lesson plans, and how they reflected their beliefs into lessons. The teachers were supplied with sources and materials such as lesson plan templates, rubrics, analyzing students' work, thinking, and learning analysis tools, integrated STEM project-based learning tools, mathematical modelling books, articles, online sources, Google Cardboard. These resources were intended to support teachers as they adapted the materials in their own context and modules.

A consent letter was sent to the homes; parental meetings were held in the school to inform the parents of the purposes and the process of the study. The classrooms were

prepared to collect data; the students were informed about the aim of the cameras and voice recorders present in the class. The researcher attended the first modules in each classroom. The researcher and the teacher had discussion sessions following the lessons. The purpose of these discussion sessions was to provide an opportunity for the teachers to reflect on their own practices, and the guide the teachers' attention to the effects of their practices in students' learning. During the rest of the modules, data were collected with video and audio recordings. After each module, the teachers submitted their reflective journal entries to the google drive document. These recorded lessons and teachers' reflective journals provided insights into (1) how teachers' implementations reflected their beliefs and pedagogical knowledge and (2) developments and challenges in teachers' instructional strategies during the semester.

A summary of the sequence of research procedures can be found in the following timeline. (See table 3.3).

Table 3.3 Teachers PCK and PB in STEM Education Professional Development Course

		Content	**Subject Matter**	**Research Related Topic**	**Procedure**	**Hours**
Analyzing Current Situation and Discovering Perceptions toward STEM	Day 1	Knowing each other Introducing research objectives and roles of researcher Introducing data collection tools	Materials: Learning and teaching Autobiography	Teachers' former experiences (Belief) Perceptions	Divide the teachers into groups. Using the worksheet ask teachers to give a written description of:	3 hours
	Day 2	From theory to practice	Materials: From theory to practice	Challenges	Divide the teachers into groups. Using the worksheet ask teachers to give a written description of: -Relation between theory and practices -Gaps between theory and practices and reasons behind that	3 hours

					A paragraph should be written explaining the ideas. Ask teachers to change their worksheets and read through their colleagues' responses. Guided discussion: -Discuss with whole group the following: -What are some challenges you face in math and science classes? -What do you think your colleagues challenge most? -What are your possible ways of solving these problems? -In what ways these challenges affect you and your students?	
	Day 3	1. Mathematics and science autobiography	Materials: Math and science autobiography	Beliefs Perceived Self-efficacy PCK (Teachers' former experiences, Knowledge of Learning, Knowledge of Teaching, Knowledge of Assessment, Pedagogical Knowledge)	Using the worksheet ask teachers to give a written description of: -Their mathematics and science learning experiences -Their understanding of teaching mathematics and sciences A paragraph should be written explaining the ideas.	3 hours

					After each teacher read their peers' autobiography, discuss about mathematics and science identity. Guided discussion: Discuss with whole group about: -When their mathematics and science identity develop? -Why do they think so?	
From Theory to Practice	Day 4	1- Focusing on Students' Mathematical and Scientific Thinking 2- Real world connections with Math and Science concepts	Materials: Videos White Board	Knowledge of Representations Knowledge of Curriculum Knowledge of Learning TPACK Pedagogical Knowledge Knowledge of Assessment	Watch Teaching Channel Videos	3 hours
	Day 5	Using videos, stories, and workshops to create a context	Materials: Books, Stories, Videos	TPACK	Pairs Story Videos Using workshop examples	3 hours
	Day 6	Understanding engineering and design process and its relationship with engineering Available technology tools	Materials: Google cardboard	Knowledge of integration of technology	Discussing available technology tools and their understanding of technology in integrated STEM education context	3 hours
	Day 7	Mathematical Modelling PBL		Knowledge of Representations	Watch Teaching Channel Videos Guided discussion 3Act Videos	3 hours

	Day 8	Assessment		Knowledge of Assessment	Guided discussion: -How to track student learning? -Examining different types of assessment tools Deciding what assessment tools to use in their integrated STEM education	3 hours
Getting ready for Practice	Day 9	Introducing STEM Lesson plan template Sharing the ideas and sources about integrated STEM curriculum		Materials: 1.STEM Lesson Plan template 2. Lesson Plan assessment form	Individually defining potential Math and Science objectives Selecting math and science objectives to plan future lessons	3 hours
	Day 10	Classroom set up for observation Creating and improving lesson plans			Set up camera and audio recorder in the classes Practice how to upload video and audio records Overviewing the standards for the lesson plans, discussing ideas, creating lesson plans	3 hours

3.5. Data Collection Tools

3.5.1. Interviews

Interviews are considered as one of the most important sources in case studies (Yin, 2009) since they allow researchers to gain an understanding of participants' thoughts, opinions, perspectives and descriptions of specific experiences (Maccoby & Maccoby, 1954). Every word that people use in telling their stories is a microorganism of their consciousness (Vygotsky, 1934, p. 170). Therefore, an individual's consciousness gives access to the most complicated social and educational issues because these issues are the

abstractions based on the concrete experience of people (Seidman, 2006). In the literature, are defined different types of interviews such as intensive interview, in-depth interview, open-ended interview, unstructured interview, conversational interview, clinical interview, long interview (McCracken, 1988) and focus group interviews (Kitzinger & Barbour, 1999; Kreuger, 1994; Morgan, 1988). In this research, two types of interviews, semi-structured interviews, and focus group interviews, were utilized.

Semi-structured interviews were conducted with three elementary teachers and all the interviews were audiotaped and transcribed. The interviews were realized throughout the semester as well as before the study started and after the study was completed. The interviews were semi-structured (Fontana & Frey, 2005) and consisted of a prescribed interview protocol within which the researcher probed and expanded the interviewees' responses and pursued aspects of each teachers' beliefs and pedagogical content knowledge in integrated STEM education. In this research, three separate interview protocols were prepared and conducted: pre-research interview, post-research interview and focus group interviews. These interviews were explained in the following titles.

3.5.2. Pre-Study Interview

In this study, a pre-research interview was conducted to obtain elementary teachers' preconceptions about integrated STEM education. Interview questions were prepared to to obtain information on the nature of elementary school teachers' pedagogical content knowledge as well as their perceptions and former experiences regarding integrated curriculum and teachers' and students' roles in integrated STEM curriculum. Two mathematics education professors who have experience in integrated STEM research were asked to determine if the aim of the interview was consistent with the interview questions. Based on their feedback, the questionnaire was edited. The pre-research interviews were conducted with the participants of the study at their available times in school and took around one hour. All of the interviews were audiotaped and transcribed.

3.5.3. Post-Study interview

Even though data were collected from classroom observations and videotapes of the lessons and teachers' reflective journals and these data sources provided detailed information of teachers' teaching, teachers were interviewed after the lesson implementations were

completed in order to be able to obtain ideas of teachers on teaching integrated STEM modules and deepen the observation data in line with the purpose of the study. The post-study interview questions were prepared based upon the data collected from each teacher. Since each of the teachers' implementations differs from each other, different interview questions were prepared for each participant. For example, when Merve extracted the estimation part of the lesson plan, the researchers asked the interview question as: "What is the reason for extracting the estimation part?". During our interview, Zeynep explained her students' thinking and she indicated that her students solved the problem with only algorithms where she expected them to use other problem-solving methods such as skip counting, modeling, or using graphs. Researcher asked: "Why do you think they solve the problems by only using algorithms?" She further explained her reasoning why students did not use multiple ways to solve a problem. Then, the researcher asked the following questions: "What if we change our words? What if we ask students: "Can you show your problem-solving by using figures or images?". In addition, additional questions were asked to each participant in order to clarify and elaborate their decisions in implementing modules.

3.5.4. Focus Group Interviews

Lederman (1990) stated that focus group is a technique involving the use of in-depth group interviews in which participants are selected because they are a purposive, although not necessarily representative, sampling of a specific population, this group being 'focused' on a given topic'. Group dynamics in focus group studies allow researchers to obtain deeper and richer data than those obtained from one-to-one interviews (Thomas et al., 1995). In other words, in a focus group setting, data through the exchange of information between the participants stimulate additional thoughts and emotions within everyone in contrast to an individual interview which is a one-way and respondent-to-questioner flow (Subramony et al., 2002). In line with this, the researcher seeks to collect in-depth data about the elementary school teachers' beliefs about each component of integrated STEM education and pedagogical content knowledge from a variety of aspects throughout the focus group interviews. Focus group interviews were planned to happen during the professional development course. The role of the researcher was to ask questions and seek elaboration but stay neutral (Reiskin, 1992). The researchers attempted to create an environment in which each teacher felt relaxed and encouraged the engagement and exchange of ideas. Because of having professional relationship with each other and experiences at their

workplace or because they met outside of the school, the teachers respectfully listened to each other, expressed their ideas effectively, and criticized or agreed to each other's ideas respectfully during the focus group studies. Focus group interviews provided rich data including (1) how participants defined the components of beliefs and PCK differently, (2) how participants' comments to each other's ideas led to conflicts and consensus regarding the components of beliefs and PCK, (3) how participants interacted with each other about the critical topics in the context. Indicating the group dynamic is one distinct feature of the focus group interview. With the aim of understanding group dynamics, which statement was made by which particular individual (Kitzinger, 1994), how each participants' statement led in what ways the rest of the groups' idea (Rabiee, 2004), focus group interviews were recorded with an audio and video recorder. Therefore, the researcher was able to observe and re-visit non-verbal interactions during the data analysis.

3.5.5. Video Recorded Observations

The teachers were observed in the classroom while teaching the first modules of their lesson plans. Observation methods can illuminate the discrepancies between what people said in the interviews and what they practice (Morgan et al., 2017; Pettigrew, 1990). Therefore, the data gathered from observations provide firsthand information about profound context information and teachers' instructional practices which are the reflection of the pedagogical content knowledge teachers own and its components (Creswell, 2012). Besides, observation produces rigor when it is combined with other methods (Meyer, 2001).

Four ways stand out in the literature about the role of the participant observers (Creswell, 2014; Waddington, 1994). These are: (1) the complete participant who operates covertly, without concealing any intention to observe the organization (2) the participant-as-observer, who forms relationships and participates in activities without making any secret of his or her roles to observe (3) the observer-as-participant, who limits his or her contact with the people being studied; and (4) the complete observer, who merely stands back and eavesdrops on the proceedings.

In this study, a fourth way has been used to carry out observation. During the classroom observations, the researcher acted as an observer without interacting with the teacher or students in the classroom setting. The classroom observations took place between February

and March 2018 during the spring semester. During the observations, video recordings and field notes were used. Video recordings of the observation provided a valuable way to capture observations (Carroll et al., 2008; Cronin, 2014). The researchers visited the videos in order to understand the details whenever participants mentioned an incident or action on a particular issue in the interview or in the reflective journals. Field notes were intended to describe the physical setting in the classroom, teachers' relationship with the students, instructional methods used by the teachers, the teachers' way of coping with students' learning needs, the use of technology, implementations of the assessment and evaluation. The video recordings were transcribed completely including every kind of teachers' talks and students' talks. The observation data along with the field notes were analyzed for the investigation of PCK components.

3.5.6. Document Analysis

Documents were used as data sources in this study and analyzed as they provide additional data to answer research questions. Document analysis is a "systematic procedure for reviewing or evaluating documents" (Bowen, 2009) and requires that data be "examined and interpreted in order to elicit meaning, gain understanding and develop empirical knowledge" (Corbin & Strauss, 2008). Yin (2009) stated that documentations are useful for several reasons: (1) documents are stable, and therefore allows researcher to review in multiple times, (2) regardless of the study, they are created in any case, and therefore have a positive effect on trustworthiness of the study, (3) they contain exact information, (4) they cover a broad period of time and many settings. Document analysis can be utilized as the only research method in a study; however, it is often used in combination with other research methods (Denzin & Lincoln, 2011). In this study, document analysis is used as an additional data source that allows researchers to develop understanding and discover insights relevant to the research problem (Merriam, 1998). Similarly, Yin (2009, p. 103) stated that "for case studies, the most important use of document is to corroborate and augment evidence from other sources". To serve the purpose described by Merriam (1998) and Yin (2009) documents were collected during the research such as lesson plans, classroom sitting arrangement documents, teachers' reflective journals, materials or sources used by teachers to create lesson plans. Some of the sources in this section were prepared by the participant teachers such as lesson plans and reflective journals; some other sources were stable and were utilized by teachers such as the sources and materials used by teachers to create lesson

plans. The sources that were prepared by teachers reflected their knowledge and beliefs. The sources that were utilized by the teachers reflected the teachers' beliefs.

3.5.7. Video and Audio Recordings

The interviews and the lessons taught by the teachers in this study were recorded with audio and video recording. The audio recordings of all interviews within the scope of the research have been transcribed word by word. In addition, the audio recordings in the lessons are also transcribed word by word. Word by word transcript is the first step for the researcher to become familiar with the data. Video recordings helped the researcher in the process of extracting from other data sources. According to Loizos (1967), video recordings are required in situations involving complex human behaviors that are very difficult to describe comprehensively by an observer. In the scope of this research, video recordings were used to understand the teachers' in-class practices in depth. Video recordings have also been useful for better understanding of the situations that cannot be noticed by other data sources.

For example, in order to better understand the interpretation of a situation in the classroom in the reflection writings prepared by the teachers after they taught the lessons, watching the teacher's experiences during the lesson with a video recording has been very useful to make sense of the teacher's conclusions. Another example showing the complementary role of video recordings is that the video recordings about how the worksheets used by the teachers in lessons were used by the students and how the teachers wrote the information on the classroom and their time were very useful in the teaching process. Moreover, watching the video recordings to better understand the expressions of the teachers' comments on each other's opinions during the focus group interviews helped the researcher explain the meaning of the data. While examining how teachers' beliefs and knowledge are reflected on the course process, the teacher's bodily and facial expressions, tone of voice, position in class, communication with his students, the use of concrete materials, such as the use of other data sources, are also examined, including unobservable movements to make inferences from the data. Especially considering that the situations in the classroom are non-repetitive and essential, the video recordings have been an important resource in analyzing the data in terms of allowing them to watch repeatedly.

3.6. **Data Collection**

Case study researchers generally blend multiple data collection methods. Stake (2013) explained that while interviews, observations, and document reviews are main data collection methods, inductive researchers are not confined to these choices. Data collection tools used in this research were: (1) interviews, (2) observations, (3) document reviews which included teachers' mathematics and science autobiography, lesson plans, teachers' reflective journal entries, classroom artifacts, images, assessment tools, (4) audio records of professional development course and lessons, (5) video records of professional development course and lessons.

This study investigated the elementary school teachers' pedagogical content knowledge and beliefs in integrated STEM modules. To gather and triangulate information, several data collection tools were used to gather deep information. Creswell (2014) describes this type of data collection as "multiple sources of information". The data within the scope of this study were collected during the 2018 semester and the Spring break. Before starting the study, the first data were obtained by conducting semi-structured interviews with all participants. Later, during the professional development course, data on 3 participants were collected through focus group interviews. All interviews were recorded in the form of both voice recording and video recording. Afterwards, the researcher made an observation in the classroom by participating in the first of the STEM modules that each teacher was processing. During the observation, the researcher took notes on actions that might be important in answering the research questions. The documents related to the lessons, such as the lesson plans, activities, worksheets, assessment, and evaluation forms created by the participants, were collected simultaneously, either as concrete material or by using google drive. Teacher journals in which the teachers expressed their opinions about the courses were completed after each module and uploaded to the google drive. At the end of the research, the interviews with the teachers were used to reflect the teachers' views on their experiences and to express their pedagogical beliefs and PCKs more deeply.

The final interviews were made with each of the teachers as soon as they finished implementing the modules so that data could be obtained while the teachers' views and experiences about their lessons were still fresh.

The data collection process can be seen in the image below (See Figure 3.3).

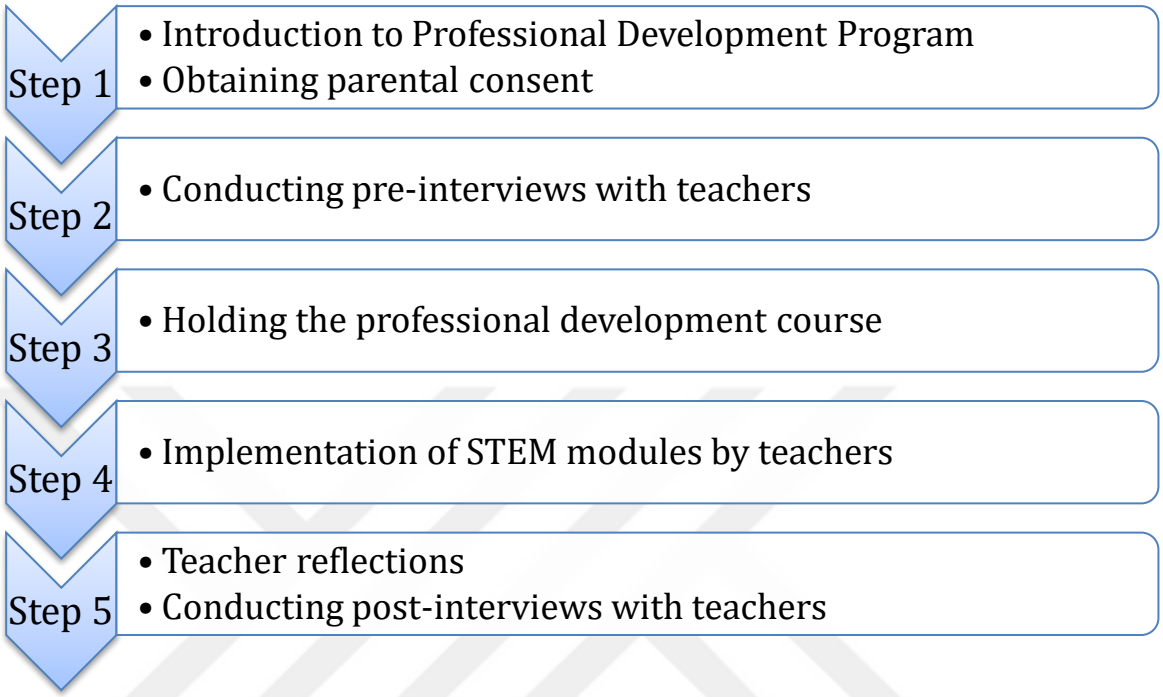

Figure 3.3 Timeline for Research

A summary of the sequence of data collection methods can be found in the following timeline (see Table 3.3).

Table 3.4 Sequence of Data Collection Phase

Feb 4	**Feb 11**	**Feb 18**	**Feb 20**	**Feb 25**	**March 4**	**March 11**	**April 26**	**April 29**
Week 1	Week 2	Week 3		Week 4	Week 5	Week 6	Week 12	Week 13
Interviews	Professional Development Meetings	Preparing Lesson Plans		First Classroom Observations	Discussions	Lessons	Last lesson	Interviews
	Documents Audio recordings Video recordings	Documents Audio recordings Video recordings		Audio recordings Video recordings Classes artifacts	Audio recordings Video recordings Teacher reflections	Audio recordings Video recordings Classes artifacts		Audio recordings

Additionally, the following table shows the interrelationship between research questions and the data collection tools (see Table 3.5).

Table 3.5 Relationship between Research Questions and Data Sources

Research questions	**Data sources**
1. What beliefs do elementary teachers have about STEM education and in what ways have teachers' beliefs been changed during the PD?	Interviews, audio records of professional development meetings, observations, documents
2. What pedagogical content knowledge do elementary teachers have about STEM education and in what ways have teachers' beliefs been changed during the PD?	Lesson plans, audio and video recordings of lessons, reflective journals, documents
3. In what ways does the professional development course contribute to teachers' PCK, beliefs and in-class practices?	Interviews, lesson plans, audio records of professional development meetings, video records of lessons, documents, observations, reflective journals

The data collection methods presented on the table above to provide a helpful contribution to answering the research questions. The details about each part of the data collection procedure explained in the following sections.

3.7. Data Analysis

Stake describes the data analysis process as "the process of making sense out of the data... [which] involves consolidating, reducing, and interpreting what people have said and what the researcher has seen and read – it is the process of making meaning" (Stake, 2013,

p. 178 as cited in Yazan, 2015). The constant comparative method was utilized to analyze the data in this research with the aim of making meaning (Glaser & Strauss, 1967). The constant comparative method is described as an ongoing process of searching for concepts and groups of similar topics. This process involves going through data again and again while comparing each element with all of the other elements. Themes and categories emerge as they represent the contents of the data. The constant comparative method has been utilized in other types of qualitative research (e.g., Kertil, 2014; Sengul, 2018) even though this method of data analysis strategy was developed by Glaser and Strauss to develop grounded theories (1967).

The constant comparative method requires researchers to zig zag between sets of data, between data and field, also between data and the existing literature with a systematic approach. In this type of study, researchers do not stop after inquiry; they even go further as they create their findings and tentative categories (Charmaz, 2001). Eventually researchers address problems in specific empirical worlds and theorize how their categories may apply to other situations (McKenna, 2013; Smart & Igo, 2010; Webster & Son, 2015).

To analyze the data within the scope of this study, firstly the data were arranged. All data are organized in historical order, considering cases and data types. All data such as pre-research interviews, all audio recordings, video recordings, field notes, lesson artifacts, teacher reflective journals and additional documents shared by teachers (photos taken during the lesson, group works, snapshots of the blackboard, etc.) accumulated in Drive cloud data storage technology. All data was then uploaded to the NVivo 12 software program. Transcripts of the interviews were created by the researcher and uploaded to the NVivo software program as soon as the interviews were completed, in memos kept by the researcher while watching the transcripts and videos of the lessons taught.

The NVivo program was used not only to organize data, but to encode data, create memos, link data, and make inferences. NVivo facilitated the storage and retrieval of data in the research process, assisting the researcher in creating and renaming codes and categories, and creating memos.

In this study, data collection and analysis continued concurrently since the constant comparative method was used. Starting from the first data obtained, they were compared with other data by considering similarities and differences (Corbin & Strauss, 2008). In the

analysis of the data, the coding process consisting of three steps was followed. These are open, axial, and selective coding (Corbin & Strauss, 2008). The purpose of open coding is to create categories, the purpose of axial coding is to establish the relationship between categories, and the purpose of selective coding is to create a story in theory development (Corbin & Strauss, 2008).

During open coding, the goal is to divide the data into categories and classify and name them (Corbin & Strauss, 2008). In the analysis of the data, the data obtained by asking the questions guiding the research were compared with each other, the relationships between them were questioned and the separated data were identified as codes. Later, the codes that were thought to express the same codes were examined again and studied under the same code. These examinations were made with the data analysis processes specified by Corbin and Strauss (2008), these are asking who, why, how, where, what questions, making comparisons, starting from individual experiences, studying language. As the data were read and analyzed, simultaneously created memos also helped to make concrete inferences about the data (LaRossa, 2005). Thus, all data were continuously compared and classified with the newly obtained data, with each code pointing to a different concept. The process of collecting and interpreting data continued until we could no longer obtain new information for each code (Strauss, 1987).

While analyzing the data, it was observed that teachers' practices in the classroom were influenced by both their PCKs and their educational beliefs, and some of their practices were the ones that were learned during the professional development course or activities inspired by them. Thus, the facts that emerged when the data were examined played a role in finalizing the research questions (Creswell, 2013). In the table below, we can see that different codes are used in the process of emerging the "Teachers' conceptualization of the state of each discipline in integrated STEM" category, but then these codes form the category (see Table 3.8).

Table 3.6 Examples of Open Coding

Interviewee	Transcripts	Open coding
Naz	*I define STEM education as follows; it is a very visual thing. Well, a word always comes to my mind so when I say STEM, I always think of design and always mathematics. I have those two things in mind: drawing and editing prototypes, always a drawing. For example, you are drawing the product you will make. You start the product.*	Building the understanding of STEM on the concepts of design and mathematics
Merve	*So let me tell you first, for example, when we try to do the first project before we know much about STEM, it is very difficult to find outcomes in terms of technology, engineering skills. We can find science achievements easily, but for example, when you are trying to add math achievement to it, it feels as if only ratio-proportion, symmetry subjects could be included in your STEM lesson plans.*	Seeing learning outcomes of science at the center of STEM
Zeynep	*Hmm, science is usually in the science problem part, so I think… We enter it as the determination of the problem. So, the solution… You know, there, I think the difference part starts there. So, it starts with basic science. So, then, the engineering, design, the engineering part for the problem, that part, that is, how and what can be done for that problem? How can you find a solution? I think the balances in engineering,*	To see the disciplines of science, engineering, and mathematics in relation to each other

	that is, finding that solution, are also based on mathematics. So, I think math is also in that part.	

While doing axial coding, the pieces of data that were previously divided into sections were brought together to be related to each other, consisting of categories and subcategories (Corbin & Strauss, 2008). At this stage, the aim was to organize the categories and subcategories appearing during the open coding stage in a way to explain the events (Creswell, 2013). The definitions of all categories and subcategories were made and their relations with each other were examined. Then, the data were re-examined in a way to better understand the phenomenon in the center, and the relationship between these categories and subcategories with the theme was determined. This process led to the discovery that the teachers' in-class practices were influenced by environmental factors, as well as by PCKs and their educational beliefs. The table below is an example of how data on teachers' beliefs form the coding scheme (see Table 3.7).

Table 3.7 Examples of Axial Coding

Theme	Category	Subcategory	Code	Description of Code
Beliefs	Beliefs about the nature of learning and teaching	Beliefs about teaching process and roles of instruction	Teacher- student relationship Traditional teaching methods Assessment and evaluation Response student questions rigorously	Teacher- student relationship: Teachers believe that a teachers' ideas about a students' achievement have important impact on students' achievement. Teachers' social and emotional interactions and relationships effect

			Planning Being a guide Role of teachers' content knowledge Time management	students' achievement in lessons.
		Beliefs about learning	Students born with static mathematical intelligence Students are natural explorers Several solutions for problems Collaborative learning Perpetual success/ failure Real life context Finding the correct answers	Students born with static mathematical intelligence: Teachers expressed their beliefs about that mathematical intelligence is static and genetic. Therefore, it has an important role in students' learning in mathematics. A student either born with a high mathematical intelligence or low and it is not easy to change this in later years.

			Joyful learning	

The last step in data analysis is the selective coding step. This stage is the one that completes the theory development. The selective coding phase starts when the generated code reaches saturation or when temporary categories are created, and includes the same processes as open coding, but this time it is limited to the core category and to the category associated with it, so it is called selective(Scott, 2009). During selective coding, the researcher creates a story by stating the relationship of the categories to the central theme (Creswell, 2013). At this stage of our study, the researcher was able to establish a relationship between the categories in the center and the effects of these categories on the teachers' in-classroom practices. In this process, questions were posed in interviews with teachers and the validity of the emerging themes and categories was once again ensured. It should be noted here that there may be more than one category representing the phenomenon being investigated (Strauss & Corbin, 1998). In this study, more than one category that explains the teachers' in-class practices has been formed. At this stage, by examining the data received from the participants, a temporary theory that explained the phenomenon in the center was formed and the findings were narrated by writing a storyline (Strauss & Corbin, 1998).

3.8. **Trustworthiness**

It is important that the inferences made in scientific research (1) represent the data obtained (2) and that the collected data represent the scope and depth of the subject being researched. While these criteria are explained with validity and reliability in quantitative research, in qualitative research they are explained with trustworthiness or authenticity. Trustworthiness generally means convincing audiences in terms of the accuracy, feasibility, consistency, and impartiality of the research. Lincoln and Guba (1985) determined 4 criteria for trustworthiness to be performed in qualitative research; these are credibility, transferability, dependability, and objectivity.

Credibility is expressed as the coherence between the findings of research and the reality and is related to the trust in the accuracy of the findings obtained from the research participants, the sources of information and the context of the research (Lincoln & Guba, 1985). Lincoln and Guba suggest using triangulation, peer examination, member checking,

prolonged engagement, and long-term observation. All these methods were used to increase reliability within the scope of this research. With the long-term participation within the scope of the research, an opportunity was found to establish trust between the researcher and the participants. In addition, the design of the research is based on long-standing observations. Since the researcher was the person who organized and implemented the professional development course, she worked with all the participants for 2 weeks and during this period, she had the opportunity to closely observe the characteristics of the participants examined within the scope of the study. In addition, by examining the practices of each participant teacher during the course practice, an in-depth insight was obtained into their educational beliefs and pedagogical content knowledge.

Another method used to ensure the reliability of the research is triangulation. When the literature is examined, it is seen that triangulation can be made with four different sources. These are to use different data sources, to collect data with different methods, to examine more than one researcher and to examine by considering more than one theory (Cohen et al., 2000; Lincoln & Guba, 1985, as cited in Kertil, 2014). In the study the methods of using multiple data sources and examining more than one researcher were used. Individual and focus group interviews, observations, video and audio recordings, documents were used as multiple data sources to provide data triangulation. During the data collection, the researcher had the opportunity to examine some of the data and discuss the findings with other researchers, with a specialist educator and with a doctoral study group at the university where she worked as a visitor researcher, and gathered the findings together with other researchers, and more than one researcher were allowed to examine the data and check the findings. In addition, using the member-checking strategy, participants were asked to read the transcripts created and check their accuracy. In addition, at the end of the study, their opinions about the findings obtained with the data gathered from them were taken into consideration.

Transferability (adaptability) is defined as the generalizability of findings and results to similar situations and events (Lincoln & Guba, 1985). The researcher is responsible for explaining the research-related properties of the context under study to ensure adaptability (Shenton, 2004). In this way, those who read the research will be able to generalize to similar situations. How this research was carried out and the data were collected in the study are described in detail to ensure transferability (Lincoln & Guba, 1985). In addition, it was given importance to explain in detail the content and process of the study, the selection of the

participants, the context in which the research was conducted, the data collection process and the timetable.

Dependability is whether there is consistency between data and findings (Merriam, 1998). In qualitative research, dependability does not indicate whether the same findings can be created by another researcher using the same data set, but whether it is reasonable to build the findings based on the collected data (Pitney, 2004). Suggested methods for providing dependability in research are a vast description of the setting, interpretive frameworks and theoretical arguments and description of the ways of data collection (Cobb & Gravemeijer, 2014; Shenton, 2004). In this study, to ensure dependability, data collection methods, data sources, data collection processes, data analysis processes are explained in a way that other researchers can understand and repeat. While creating the data collection tools, an expert mathematics educator helped the researcher. In addition, a part of each data set was randomly selected and analyzed by a field expert educator and a doctoral research group, and consistency was observed among the analyses made. In cases where consistency couldn't be observed, a compromise was reached through discussion. In addition, by sharing the theoretical framework of the research with the reader, it was explained according to which general assumptions the obtained data were analyzed and how the findings obtained within the scope of this study emerged (Pitney, 2004).

Confirmability (neutrality) is about the objectivity of the researcher. The fact that a study's findings reflect the experience and views of the participants and not the characteristics or preferences of the researcher is defined as neutrality, and triangulation, thick description of the data collection tools, and analysis of data are ways to achieve this (Shenton, 2004). To ensure confirmability, all the processes within the scope of this study, the decisions made during the research process and why such decisions were made were described in detail. In addition, attention was paid to include quotations from interviews and observations while describing the findings (Yin, 2003b).

4. RESULTS: WITHIN CASE AND CROSS CASE ANALYSIS

In this section, a holistic summary of the findings is given in the table. I began presenting the findings of the research with teachers' pedagogical beliefs about STEM education and continued with STEM PCKs since this is the order of the research questions. Teachers' pedagogical beliefs about STEM education consist of three components. These are: 1) teachers' beliefs about nature of learning and teaching, 2) teachers' beliefs about nature of STEM, 3) teachers' beliefs about context.

1) With teachers' belief about the nature of learning and teaching, I explained how teachers' learning takes place in STEM disciplines, how teaching should be implemented, and how teaching environments should be arranged for the most effective learning.

2) With teachers' beliefs about nature of STEM disciplines, I have explained teachers' beliefs about the nature of S, T, E, M disciplines, how these disciplines will play a role in the STEM modules to be designed, teachers' previous experiences and feelings from these experiences.

3) I explained the teachers' beliefs about the context, the teachers' working conditions, the effect of the atmosphere in their school on their profession, the education system, the approach of their students, their parents, their education in the process of becoming a teacher and the effect of this education on their competence.

Then I presented the teachers' STEM PCKs. I started with Teachers' Orientation Towards STEM, because in the literature, this component plays a role that shapes and affects other PCK components, and it has an important place among the data. The information on which discipline the teachers will focus on in integrated STEM education, STEM-specific teaching approaches and student outcomes that teachers consider important are explained within the scope of this component. During STEM education with Knowledge for Teaching, I explained teachers' knowledge about teaching strategies, their knowledge about the curriculum, their knowledge about their students, and their knowledge about assessment and evaluation. With the Knowledge of Context, teachers' knowledge of where they work was examined in terms of its impact on their teaching. I explained the methods of bringing together disciplines specific to Integrated STEM education with Knowledge of Integration and the methods of using disciplines in their teaching. And lastly, as a 21st century teacher,

I studied the professional development of teachers. Finally, while presenting the findings, I also looked at any changes and improvements under each component. Thus, I aimed to see the effects of the professional development course, if any.

Table 4.1 Each Teacher's Pedagogical Beliefs About Integrated STEM Education Profile Over the Course of the Study

STEM Pedagogical Beliefs Components/ Participants		**Merve**	**Naz**	**Zeynep**
(1) teachers' beliefs about nature of learning and teaching		Mathematical intelligence is innate. Finding the correct answer through the clues the teacher gives Teaching according to the student's interest and context Teaching while doing and experiencing STEM education should be suitable for constructivist approach Teachers need to be more equipped for STEM ed	The teacher is the person who conveys knowledge Getting the students to answer the question on the board (s)he asked to the class Children are born explorers Students' inner motivation STEM education should be suitable for constructivist approach (students are active) Learning through group work Social emotional learning supports students' positive outcome. STEM education may be contradictory with the learning outcomes through teaching Assessment could be difficult in STEM education	Children are born with the gift to discover Making fast calculations in mathematics is an achievement The teacher is the person who conveys knowledge The student should express the knowledge as the teacher explained. Learning by comprehending and questioning Learning while having fun is more permanent STEM education should be suitable for constructivist approach The teacher must play the role of a guide in STEM education
(2) teachers' beliefs about nature of STEM disciplines	Teachers' Feelings towards STEM disciplines	Negative feelings towards Math and Science	Negative feelings towards Math and Science	Positive feelings towards Math and Science
	Teachers' Own Experiences towards STEM disciplines	Traditional learning experiences in mathematics and science lessons	Traditional learning experiences in mathematics and science lessons	Traditional learning experiences in mathematics and sciences All experiences in Technology and Engineering disciplines have been developed during professional years.

		Positive attitudes toward science lessons improved when constructivist approach was employed Negative attitudes have turned into a negative sense of belonging Negative attitudes formed in earlier years lay the foundation for the experiences in the following years All experiences related to the disciplines of technology and engineering developed during the years of actual practice.	A lack of the settings offering contribution to the development of Science and Mathematics education throughout their career Traditional learning experiences until university, the development through social and emotional support of the mathematics teacher during preparation for university and positive experiences through a constructivist approach in science lessons All experiences related to the disciplines of technology and engineering developed during the years of actual practice.	
	Teachers' Conceptualization of The State of Each Discipline in Integrated STEM	Science and engineering are central disciplines Only certain units from the discipline of mathematics could be incorporated into STEM 21st century skills are also incorporated into the discipline of technology The cycle of engineering is at the center of the discipline of engineering	Engineering and mathematics are central disciplines The theme comes from science discipline Technology can be used for gaining students attention Only certain units from the discipline of mathematics could be incorporated into STEM.	Science and Engineering are core disciplines Mathematics is related with solving engineering problems The theme comes from science discipline Technology can be used for designing materials.
	Teachers' Beliefs about the Nature of Each Discipline	Merve's earlier beliefs show that she perceives mathematics as relational Instrumental beliefs about mathematics improve within the scope of the course She divides mathematics into two at the end of the research as real (instrumental) and school (relational) mathematics Creating prototypes and the cycle of engineering; the discipline of engineering Technology, reasoning, creative thinking etc.	Naz's earlier beliefs shows that she has relational beliefs in mathematics Later she develops a belief as mathematics can be seen under two subsections: mathematics in real world and school mathematics She benefits from technology at the stage of drawing attention. Drawing engineering design is at the center of the discipline of engineering.	Mathematics and Science is instrumental and should be taught in real life context Engineering is related to problem solving Technology is related to electronic devices

3) teachers' beliefs about context	Country	Professional development is not given enough importance for public school teachers Curriculum is overloaded Turkish educational system is insufficient to put into action innovations	Professional development is not given enough importance for public school teachers Turkish educational system is insufficient to put into action innovations Due to the "following current curriculum in given time" obligations limit her ability to use new methods in her class	Turkish people are not successful in mathematics. Teachers should spare more time for mathematics. Students already develop a prejudice that mathematics and science are difficult before they start school The intensity of the curriculum prevents the application of innovative methods. Turkish educational system is insufficient to put into action innovations Professional development is not given enough importance for public school teachers Teachers are not given a university education good enough to make them efficient teachers all over the country.
	Community	Family support is missing Families stand up for traditional teaching methods	Family support is missing Families stand up for traditional teaching methods	Active learning is not supported by the community. Culturally reflective pedagogy has an important element in effective teaching
	School	School needs to supply technological tools and laboratory	School needs to supply technological tools and laboratory Poor school conditions limit her ability to develop her PCK	Lack of materials pushes teachers to use traditional methods
	Student	Students' cognitive competences differ between their grades. STEM ed may help students to develop 21st century skills STEM may help her students to develop self confidence	Students who learn slowly and with disability would benefit more. STEM ed may help students to develop 21st century skills Her current students' social skills are underdeveloped. Students are needed to develop their social skills.	Students' ability and competency requires more than given time STEM modules help students to develop positive attitude regarding mathematics and science.

		Positive science and math identity Group study is required for STEM ed		
	Teacher	Elementary teacher teaches integrated as usual. STEM ed may help teachers' professional development.	STEM ed may help teachers' professional development.	Teachers have biases towards competent students. Teachers are unqualified in the field of mathematics.

Table 4.2 Each Teacher's Pedagogical Content Knowledge of Integrated STEM Education Profile Over the Course of the Study

STEM PCK Component/ Participants		Merve	Naz	Zeynep
Knowledge of Teaching Strategies	Knowledge of subject specific strategies	Mostly the teaching strategies in mathematics and liv formation and partly in engineering are included. The methods which will enable students to learn actively dominate. The teaching strategies related to the discipline of technology are excluded. She adapted the strategies applied in professional development course to her lessons (cooperative learning, class management, developing communication skills) Engineering design cycle was utilized.	Mostly the teaching strategies in science and engineering and partly in mathematics are included. It was made possible for students to be active through Hands-On activities teaching is generally teacher-based. The teaching strategies related to the discipline of technology are excluded (technology was utilized to watch videos or to show PPT presentations during the lesson) These strategies applied in professional development course were used. She wanted to benefit from engineering design process and mathematical modeling, but because they were poorly connected to the standards, they were put in the category of "misapplication lesson".	Mostly the teaching strategies in mathematics and liv formation and partly in engineering are included. She is generally teacher based. She tried student base methods, but she gave up because of unfavorable conditions of the setting (the number of students, preparedness of the students) The teaching strategies related to the discipline of technology were excluded. (Although she tried, she couldn't practice them because of insufficient environmental conditions). She adapted the strategies applied in professional development course to her lessons (3-Act- Modelling, Post-its problem-solving strategies idea exchange, Think-pair-share, Microphone method, Group study).

	Knowledge of topic specific strategies	Representations: arrays and number line Used these strategies to explain how to solve problems	Representations: She used fraction strips, portioning and length models	Focused on strategies for her students to grasp the main ideas in problems: Notice-wonder Representations: strip diagram It is seen that she particularly focused on activities for her students to understand the problem and that he placed mathematics in the center of her lessons.
Knowledge of Curriculum		She has a grasp of the learning outcomes and changes in the curriculum. The disciplines of mathematics and liv information address to different cognitive stages of students. The emphasis is on learning outcomes (related to math) towards establishing links between disciplines in the discipline of engineering and on the process of cooperative learning The context has a great effect on lesson plans (choosing learning outcomes in parallel with the curriculum) The discipline of technology is not included in the process.	Naz is aware of the learning outcomes and changes in the curriculum Because there are no accusations in the fields of Technology and Engineering imposed by mandatory curriculum, she selected acquisition from additional sources. The learning outcomes in the field of engineering are appropriate for her students. The learning outcomes in mathematics and science generally appeal to low cognitive levels of the students. She didn't address to the learning outcomes in the field of technology. The context influences lesson plans (the obligation to choose an acquisition parallel to the curriculum).	She is familiar with the learning outcomes and changes in the curriculum. She addresses to the different cognitive stages of the students in mathematics and live information. Their learning outcomes in the disciplines of Technology and Engineering are not included in the process. The context has a great effect on lesson plans (choosing and acquisition in parallel with the curriculum, using the environment of the students as an acquisition.

Knowledge of Student		She knows what the interests of the students are. She knows about the background of the students. In STEM education: 1. We see that all the students actively participate 2. Written communication skills of the students are not as developed as their verbal communication skills.	She has high expectations from her students. Naz managed to attract students' interest successfully by using the context they were living in. Naz built her lesson plans on her students' prerequisite knowledge in each module She observed that some of the students who had never attended lessons attended actively during STEM applications.	She considers the prior knowledge of the students. She knows about the students' social cultural backgrounds. There is much emphasis students' understanding words problems in STEM education. -Because she usually taught in conventional ways, the development of the students couldn't be observed
Knowledge of Assessment		In the beginning. 1. She has insufficient knowledge of assessment and evaluation. 2. STEM education is lacking in assessment. It is only possible to measure 21st century skills of the students in STEM education. In the process of research, Merve. 1. Improves her knowledge of what and how to assess. 2. Develops her knowledge of formative assessment tools and gains experience.	At the beginning of the research, she had poor knowledge of the purpose of assessment, how they would be conducted and its diverse methods, but she improved her knowledge during the research. She tried to learn more about how students learn through open-ended questions. She tried to improve students' metacognitive awareness through gallery walking. However, she had poor implementation regarding formation of assessment. She didn't explain her expectations from students clearly enough during learning activities she prepared.	In the beginning. She has insufficient knowledge of assessment and evaluation. In the beginning. She has insufficient knowledge of assessment and evaluation. She is improving her knowledge of assessment model during the research. She states that the manners of the students regarding how to specify problems and solve them, their skills of working together, their

		3. States that she can monitor students' cognitive developments better with formative assessment rather than written examinations.		designing capacity should be measured in STEM education. In her applications, she created problem solving worksheets
Knowledge of Technology Integration		She didn't receive any formal technology education. She didn't incorporate technology Learning outcomes into her lessons. She utilized technology in. 1.Developing her own lesson plans, 2.Collaborating w her colleagues, 3. Reflecting on her own learning 4.During her lessons for presenting ideas	She didn't receive formal technology education. He didn't incorporate her technology learning outcomes into her lessons. She employed technology in. 1.Developing her own lesson plans, 2.Collaborating with her colleagues, 3. Reflecting on her own learning 4.During her lessons for presenting ideas Her context knowledge about school roles a play to shape her knowledge of integration of technology.	She didn't receive formal technology education. She didn't include technology Learning outcomes into her lessons. She employed technology in 1.Developing her own lesson plans, 2.Collaborating w/ her colleagues, 3. Reflecting on her own learning 4.During her lessons for presenting ideas She tried to use technology in conceptual learning, but conditions of the environment restricted it.
Knowledge of Context		School and country conditions have a negative effect on teaching effectively. - lack of materials -lack of family support/involvement	School and country conditions have restrictive effects: -lack of materials -lack of family support	School- country- student conditions have negative effect on teaching effectively -lack of materials -lack of family support

		-limited the integration of subjects (mandatory curriculum) She made it possible for "context about student education to be organized in a way to relate to the life of the students She planned her lessons by considering: - children's interests - their cultural and social environment - the conditions in which children live - the daily events they go through	-limits integration of subjects (mandatory curriculum) -utilizing technology only for monitoring images and videos Knowledge of student context to make her lessons relevant to her students' lives	-limits integration of subjects (mandatory curriculum) -large class size Context about students has positive effect: - She organized the themes in accordance with the living conditions, interests, and experiences of the students.
Knowledge of 21st Century Skills		She both incorporated 21st century skills into her lessons and monitored how the students learned. Life and career skills related to each module's theme. Group studies were beneficial for students. Focused on life and career skills, collaboration, problem solving, critical thinking, creativity and innovation and communication.	Focused on collaboration and life and career skills	Collaboration and problem-solving were present in her applications. Because the preparedness of her students was not sufficient, she didn't use collaboration in the subsequent lessons. She's stressed the importance of life and career skills, but she didn't add them to her practices.

Integrative Thinking		Context integration Mathematics is central subject, used the context from Life Sciences, Technology and Engineering disciplines.	Context integration Central disciplines are science in the 2nd, 3rd, and 5th modules and mathematics in the 4th module, and both mathematics and science in the 1st and 6th module Used the context from technology and engineering disciplines	Context integration She centered mathematics and she utilized objectives from life sciences as a context.
Professional Growth		Development in: knowledge of assessment, knowledge of teaching strategies, knowledge of students, knowledge of 21st century skills, knowledge of integration Convenience of current professional development course	Convenience of current professional development course Limited development because: -her low self-efficacy in implementing integrated STEM education. This may prevent Naz to develop throughout the research -impact of low CK Good development in. Knowledge of teaching strategies, Knowledge of student, Knowledge of assessment, Self-assessment	Development in: knowledge of teaching strategies, knowledge of assessment, knowledge of 21st century skills, knowledge of context Convenience of current professional development course

4.1. WITHIN CASE ANALYSIS

4.1.1. CASE 1- MERVE

Merve's instructional beliefs about stem education are examined under 3 subtitles as 1) beliefs about nature of learning and teaching, 2) beliefs about nature of STEM disciplines and finally 3) beliefs about context. These beliefs show that she associates constructivist beliefs with STEM education and traditional beliefs are associated with general education. Merve developed positive beliefs about conceptual teaching within the scope of this research, but she nevertheless didn't completely give up her beliefs about rote learning. Instead, she held these two beliefs together and attributed her beliefs about conceptual learning to integrated STEM model and her beliefs about traditional learning to general education. Her contextual beliefs in a way explain why she retained her previous instructional beliefs while developing new educational beliefs. Although she believes that Turkish system of education is not a system suitable for implementing innovative methods, and although innovative methods would be to the benefit of the students, because of physical drawbacks at school as well as of poor support from families and although she believes that teachers will contribute to her professional development in a positive way, she is of the opinion that it is impossible to implement this model. Her contextual beliefs go through a transformation in a way to retain both her constructivist and traditional beliefs.

4.1.1.1.1. Beliefs about Nature of Learning and Teaching

In this section, Merve's beliefs about the nature of learning and nature of the teaching process and roles of instruction were reported. The teachers' beliefs were evaluated with the help of pre- and post-interviews and during the professional development program. Merve's beliefs have been presented chronologically, with the aim of understanding the development of beliefs, if any.

The results of the data analysis have shown that Merve has conflicting beliefs. When we examine her conflicting beliefs as regards learning and teaching in detail, we see that Merve's beliefs about the nature of teaching and learning in general differ from her beliefs

about the nature of learning and teaching in STEM education. She usually associates learning and teaching with her beliefs about traditional learning, and her beliefs regarding STEM education are constructivist. In other words, her beliefs about STEM education underwent a change towards the constructivist approach.

The interviews made at the beginning of the research portray Merve's conflicting beliefs. She remarked that she believed in the effect of innate traits on the success of students as well as in the importance of the methods based rote learning on the one hand; she emphasized the importance of settings which enabled students to construct knowledge on their own on the other hand.

Merve expressed her beliefs about the fact that students' success in mathematics results from their innate characteristics as follows: "I actually think that genetic factors are effective (…) Yes they can be developed later, but in my opinion, humans have something called mathematical intelligence. (…) For example, when I now look back at my own childhood, I see that I didn't have mathematical intelligence. (…) Mathematical intelligence is inherited from mother." (An excerpt from interview with Merve)

Merve also emphasized the key role of memorization in determining the achievement of students. She made an emphasis on having correct answers in mathematics classes. She also said that she didn't give any point in the exams if a student didn't solve a problem in the way that she taught in the classroom. Merve believed that learning mathematics was equally the responsibility of teachers and students; that being said, Merve asserted that teachers who taught with non-traditional methods had a positive effect on students; and students' role in learning comes from their intelligence.

On the other hand, the interviews revealed that Merve underlined the fact that students should assume the responsibility of learning in STEM education. When her opinions regarding students' role are examined, it is seen that she regards STEM education as a process during which student should play an active role and take on responsibility. She believed that in integrated STEM education, (a) students need to have the ability to influence the world around them, and (b) they must play an active role in problem solving both in school context and in their own lives. She explained how she valued student involvement in integrated STEM educations as:

> Besides, the most significant part of STEM for me is the point at which the student improves his or her reasoning skills in the face of a problem. In a way, he or she shouldn't accept what is offered in certain situations; he or she should produce something different, find a solution. In my opinion, the most important part of STEM education for children too is this.

In-depth interviews conducted to understand her conflicting believes better revealed that her constructivist beliefs were mostly related to integrated STEM model.

> R: Well, for example, do you think that the role of the teacher is different in STEM education from the one in traditional education?
>
> Merve: In traditional education, the teacher is the generally something like a person who conveys information. Saying to the children that two by two makes four, doesn't it, and not making them give the answer yes. In STEM, when you do your best to make that child find the answer, errrr, and when the child finds it, questioning how he or she found it; because you tried to motivate him or her to use reasoning or to think differently.... Yet in STEM education, you have to make preparation in advance, think about something suitable for that lesson, design something, and direct the questions asked by them. For this reason, its difference from traditional education is that it leads you to be more prepared. Well, it leads you to prepare a plan B for the different questions to be asked by the children.

Moreover, it is seen Merve's constructivist approaches concerning the nature of learning and teaching in stem education came to the fore throughout the research. " Well, during the period when you go through STEM education, you are actually not the person who imparts information, but you are trying to be a person who helps the child to find information, to discover it. Indeed, this is something more difficult than giving information, in my opinion, that is giving information directly. Trying to direct the student with the help of the right questions and asking the right questions turns into a process that requires much more comprehensively; that is why this is a method which makes you a bit more tired. There is one correct answer. It is much easier to give it in a monotonous way, but you have to be involved in the event all the time while practicing STEM education."

Merve explained her beliefs about the importance of promoting student agency in integrated STEM education. Merve had a strong interest in meaningful student involvement and highlighted the need for students to take on responsibility to develop thinking skills. She described a teachers' role as a guide and said that she expected a teacher to draw attention at the beginning of a class, have students question the content and form a class according to students' interests. In her idea, a teacher must be helpful for students to learn by themselves. Besides, during the professional development course she developed beliefs about lesson planning.

> R: What do you think are the most important factors for teaching?
>
> Merve: It has never occurred to me that making a plan is so important, but your plan must be the most important thing to you, and you have to step into the classroom in a prepared way. Actually, the child will cover the lesson; you will only be the person who directs. I mean you will draw his or her attention and then you will help the lesson to take a form with his or her questions. I mean it is like you will be usherer to self-learning.

In summary, Merve' beliefs about the nature of learning and teaching in STEM education fall into two groups, in general and in STEM education. While her constructivist beliefs represent her beliefs regarding education, her traditional beliefs represent her beliefs regarding STEM education overall. It is understood that Merve's traditional beliefs resulted from the education she was involved in during her own schooling. The results of the practices in this research have revealed that Merve's beliefs changed in a way to reflect constructivist education more.

4.1.1.1.2. Beliefs About the Nature of STEM Disciplines

The pre-interview, professional development sessions and mathematics and science autobiography were analyzed to understand Merve's beliefs about the nature of the science, technology, engineering and mathematics and integrated STEM disciplines.

Her beliefs of the nature of the science, technology, engineering, and mathematics will be analyzed under four subheadings. These are: (1) teachers' feelings, (2) teachers' own

experiences. (3) teachers' conceptualization of the state of each discipline in integrated STEM and (4) teachers' beliefs about the nature of each discipline.

Analysis of data indicated that she had negative experiences about the disciplines of mathematics and science in the past and as a result she has negative feelings in this regard. The unfavorable experiences she had about these disciplines in the first years turned into unfavorable identity in the following years. Because she didn't receive formal education in engineering and technology during her schooling, negative perceptions about these disciplines developed while she was pursuing her career. Merve improved her beliefs regarding the disciplines of engineering and technology during the professional development course she attended through her own efforts. She views the discipline of engineering as related to the cycle of engineering and material design, whereas she views the discipline of technology as resulting from 21st century skills during the professional development course.

Merve has negative feelings towards Mathematics and Science. Merve's negative image comes from her past experiences in the school while she was a student. Her negative feelings can be seen in her Mathematics and Science Autobiography document. She emphasized how she remembered her feelings over the classes, curriculum or lessons. She has an overarching reminiscence about her education which was a traditional one and there were no materials or innovative teaching methods involved in any grades from elementary to undergraduate. She expressed her memories about her Mathematics and Science learning as:

> All I remember about the primary school was that I changed teachers frequently. I have no memories about how I learned letters, how I felt in mathematics and science lessons. There is no detail in my mind about how we covered lessons. (…) I never managed to solve problems. (…) I remember the experiments we conducted in science lessons. When I passed to the secondary school, this feeling of failure continued. I never used to feel at ease. I always forced myself to understand, and I studied a lot. We never used any materials while covering the subjects, we covered them in an ordinary way. (…) I remember that biology lesson drew my interest in high school. Laboratory lessons in chemistry. Nevertheless, I wasn't quite successful. I chose the field of TM (Turkish- mathematics), and therefore I always struggled a lot to learn just mathematics. I remember laying myself out to learn trigonometry. I

> have faint memories about these two fields because I didn't feel comfortable. I remember about the cell model we made from gel at university. Our examination of blood types.

When we examine Merve's negative experiences concerning STEM disciplines, it is seen that her negative experiences towards mathematics at primary school led to a feeling of apprehension and failure about this discipline and in the following years such feelings turned into an identity. A close examination of Merve has revealed that her feelings and sense of identity in the first years had a significant effect on the following years.

The written statement below illustrates some of the main characteristics of her feelings toward Mathematics and Science lessons.

> I remember that I was extremely scared of mathematics at Primary School. I saw myself as a failure. Then I passed to the secondary school, this sense of failure continued. I never felt comfortable… I remember that biology attracted my attention at high school. Chemistry lessons, laboratory lessons. But I wasn't still quite successful. I mean I was never a successful student in the field of science and math throughout my education. In fact, my mathematics and science education are full of negative memories in general. I remember that the teacher once declared me to be a failure at primary school because I couldn't solve a problem. This declaration used to demotivate me further and led me more into failure. (.....) I never became a student who could solve a problem and bring the solution on time, because that was what mattered to the teacher and that is why I was close to zero. I grew up feeling close to zero all my life.

As she said, her negative feelings started to develop in the first years of her education. She thinks that because she cannot solve the problems, she was unsuccessful. It can be understood that solving problem in each period of time was also an indication of being successful in mathematics lessons. Besides, Merve's expressions show that her teacher embarrassed her in front of her classmates. This behavior of her teacher's damaged her self-confidence and made her feel failed.

She told about her feelings related to Mathematics and Science education when I asked, "What are the three keyword that come to your mind?":

> Fear- number- laboratory are the words that come first to my mind. I was always afraid of these lessons because numbers were always tough for me and the only part of these lessons that I enjoyed was to experiment (…).

The fact that they made me feel a failure always affected me more adversely. Perhaps hearing the sentence that Merve's mathematics is “not good at all”.

Also, she emphasized that being called unsuccessful by teachers affected her resentfully. It can be seen that her only positive experience was when she had a chance to learn with scientific experiments and group studies. She thinks she had a chance to learn from other students during the group studies and it was practical for her. Like when she refers to her experience in high school Biology and Chemistry classes:

> (....) Conducting experiments was the only part of these lessons that I enjoyed. (.....) we used to hold group activities at the university. I have always liked activities involving practice. It makes me feel better to have somebody to complete the missing parts. I was better at group work and applied fields. That is, learning while doing is a more efficient method for me.

When I asked them when their Mathematics and Science identity developed, and how, Merve replied to this question as follows:

> R: Now when you look back at your experiences concerning mathematics and science in your history, when do you think a student's identity of mathematics or science starts to develop? And what triggers it? How does it start and how does it develop in your opinion?

Because of her perpetual negative experiences in mathematics and science classes, she said she started to develop a negative identity towards these disciplines while she was at elementary school. In her words: “I never managed to solve the problem at primary school. When I passed to the secondary school, this feeling of failure continued. I never felt comfortable.”

When I challenged her ideas about what constituents described a students’ mathematics achievement, she figured out that: “But it is not directly the teacher who makes a child successful or unsuccessful.”.

Then I asked her, “What is a teacher’s role in students’ achievement?”. She answered:

> Our role may change depending on the type of the teacher. If the teacher is somebody who tries to teach through various activities, the teacher pushes the student to 10; yet if the teacher is someone who adopts a monotonous way of teaching, maybe he or she pushes the student towards 0 or towards feeling a failure; for example, I feel close to 0 for that reason.

During the professional development meetings, Merve said she didn’t remember how she had learned mathematics. “Merve: "I don’t know whether you remember but I don't even have a memory of my primary school and how I learned mathematics.", nevertheless after Zeynep and Naz talked about how their mathematics learning experience were, Merve remembered her tutors’ teaching method helped her to answer more questions in the Undergraduate Placement Examintion which an exam for the placement of students to university (college).

This memory took her to making two deductions. First, she thought that her tutor showed how to solve a problem and then asked her to copy his method. She stated she was being asked to memorize the solutions of certain problems. This way she couldn’t develop instrumental understanding; instead, she was able to develop limited relational understanding. She denoted that she worked very hard and with the help of her tutor, she had 10 correct answers out of 15 questions and according to her, she was only able to do this. This shows that her mindset around mathematics was already fixed by then.

Second, to Merve, students not only develop positive or negative identity towards mathematics and science during their elementary grades but also their identity tends to remain the same even in the college year. Her argument runs as follows:

> At the primary school, yes, but not fully established. Mostly it develops there. Yes, it can really change. However, should they be those experiences of mine for example, namely, as I learned at the primary school? (…) I remember laying myself out all the time in order to learn mathematics. I remember I always struggled with it alone at home. (…) I remember that I only just answered 15 questions correctly at the University entrance examination, but I really tried hard to answer those questions and that was all that I could do. I couldn't do anything more. That was just I did.

> Turkish lesson, yes, was always excellent. Perhaps all the answers were correct, but that was the best I could do in mathematics, and I did that much.

Regarding to the state of each discipline in integrated STEM, Merve see Science and Engineering as the central disciplines in integrated STEM education. She also implies that her past experiences in integrated STEM education include a few critical areas from mathematics. Merve has misconceptions concerning the discipline of technology and these misconceptions formed in the professional development course she previously attended. Besides, Merve believes that the foundation of the engineering discipline lies in the cycle of engineering.

First, I will explain how science and engineering became her focal point in integrated STEM education. Then, I will explain her ideas as to using only a few critical areas from mathematics and her ideas about technology.

Merve's conceptualization of the state of science in integrated STEM education relies on her first attempts to learn about integrated STEM education. She said that she had first heard about integrated STEM education from one of her colleagues who was studying on this topic. They started to do a project in which they teach with integrated STEM education with the focus of enhancing students' interest in pursuing careers involving science, technology, engineering, mathematics. However, they had concerns about whether they could implement an accurate curriculum. Then, she was involved in a professional development course in a private university in Istanbul where Merve's conceptions of each discipline in integrated STEM education were formed. She explained her experiences and roots of her beliefs in the following way:

> Merve: I was introduced to STEM by a colleague of mine 2 or 3 years ago. Afterwards, we tried several things of our own accord, but everybody had a different perspective about STEM. We didn't know exactly what the truth was, but we carried out what we had researched. Subsequently, we attended at professional development course for 4 days.

> R: So how do you see the relationship between disciplines in STEM education, for example what is the role of mathematics or the role of science? What is the role of Technology and Engineering in STEM education?
>
> Merve: Let me say, the first time yes, when we attempted to do a project without knowing much about STEM, we had great difficulty finding standards for Technology and Engineering skills equivalent to the standards. We can easily find Science standards but for example when you try to add mathematics standards to them, it seems as if only the subjects of ratio- proportion and symmetry could be included in STEM lesson plans.

In terms of emerging areas in mathematics, Merve indicated that ratios, proportional relationships, and symmetry were the topics that they used mostly in STEM education. She expressed her conspicuous observation on how they tried to fit mathematics hard into the STEM lesson plans.

In addition, Merve explained her views about the nature of the technology discipline in this way:

> I used to think that there should be really something technological in technology but in fact I saw that technological standards were not necessarily in the form of conducting research or well using 3D printers, designing something, producing this; indeed, when I say technological standards, I mean that such things as the skills of reasoning, thinking differently, dreaming about the next step are also included in these standards.

I asked how her initial thoughts was regarding the nature of technology in integrated STEM education to understand her point of view better, and she said:

> For example, when we first set out, we started to do a project with stem, bought we had concerns because we didn't use technology at all during that period. You know, technology is one of the most important parts of STEM, but we believed we didn't use it at all.

Then I asked her if she thought in a different way currently, she said:

> Yes. For example, in the STEM education we received, the tutor explained that technological standards were not like conducting research on a computer or bringing mechanical items together but in fact gaining ability of analysis, well, creating prototypes and bringing concrete materials together were actually some sort of technology.

According to her statement, her initial image of technology contains skills such as doing research through the internet and using 3D printers. After she participated in the professional development course in a private university in Istanbul, she considered reasoning skills, creative thinking and imagining the next step as technology. It can be inferred that the former professional development course gave her the wrong impression of technology, since creative thinking and innovation skills are the components of 21st century skills.

Developing teachers' understanding and knowledge about technology component was one of the objectives within the scope of this study. Teachers were able to learn and implement technological tools during the professional development course. However, technology component is very limited in Merve's lesson plans. Besides, limited implementation was observed in her classroom practices during the study. An analysis of the post-interviews revealed that Merve's contextual beliefs prevented her from providing accessible educational technology in her practices. Besides, her predisposed assumptions about technology component prevented her from developing her knowledge and practices. Merve expressed her beliefs as:

> In the previous course we attended, we had actually talked about technology as only something, that is, not just something like a child sitting and making codes, not something like drawing on the computer as we considered it. For this reason, I don't think this is a big shortcoming. It sounds enough to me even when a child adds technology and dreams about it as well as thinking something like what sort of Technology he or she would include or what he or she would add.

As described earlier, Merve believes science is the central component of integrated STEM education. Moreover, she believes engineering is the other central discipline in integrated STEM education. She described her beliefs such as: "Engineering but, I think it is something fully in STEM..."

Merve stated that most of the lesson plans were centralized around engineering activities during our post interview. Her beliefs about central disciplines in STEM education didn't change in the context of this study; however, her understanding of the state of mathematics in STEM education changed. An analysis of interviews reveals that Merve included mathematics topics more often in the lesson plans. Besides, she highlighted real world connection with mathematics discipline more often in her implementations. She said: "Following these practices, the children realized that mathematics is used in many engineering fields and that mathematics is highly needed. For example, they understood in the last lesson that mathematics is there even to grow flowers.".

In summary, Merve believes science and engineering are the two of the central disciplines of the integrated STEM education. She implied that engineering consists of engineering design loop and creating prototype. While at the beginning of this study she thought that only limited areas in mathematics are involved, during this study she developed new beliefs about the involvement of mathematics disciplines into the STEM education. In contrast to her initial beliefs, in which she sees mathematics as a collection of tools such as procedures and formulas, she stated at the end of the study that she believes mathematics could be a tool for sensemaking. Her initial image of technology in integrated STEM education consists of 21st century skills such as creative thinking and innovation. She holds misconceptions about the technology component and her contextual beliefs prevented her from developing her knowledge about technology component.

When we examine her beliefs about the nature of disciplines, it is obvious that Merve kept her previous beliefs throughout the research, while she developed new beliefs regarding the discipline of mathematics. Furthermore, she associates the discipline of engineering with the cycle of engineering and making prototypes, whereas she associates the discipline of technology with such 21st century skills as reasoning, creative thinking etc.

When we examine Merve's beliefs prior to the research, we can deduce that she associated mathematics mostly with memorizing certain concepts and rules as well as teaching certain problem-solving methods through constant repetition. However, Merve changed her beliefs and developed them during the professional development course. She articulated her belief system between the theoretical belief and practical belief. She asserted

this disjunction as the difference between “mathematics in real life context/ real mathematics” and “school mathematics”. According to her, she was exposed to the school mathematics which she delineates as ‘contrived mathematics’. An excerpt from our one one one meetings explains her changing thoughts.

> You know there is a conversation that mathematics is actually the daily life itself; I myself never remember something which I could make use of perhaps because we have never learned anything like this. Yes, life is in fact some sort of mathematics; that's right. But perhaps because we weren't taught mathematics in this way, I have never felt so during all my life. What we have learned is contrived mathematics.

During the professional development meetings, she, then, challenged her own idea about which mathematics should be taught. She emphasized that, if she could teach students how to learn mathematics, students would also become successful in the high-stake tests. She highlighted her lack of knowledge about the nature of mathematics and science disciplines, and her lack of knowledge about her content knowledge or knowledge of students in teaching mathematics and science. She provided rich feedback for the inquiry regarding the nature of mathematics and science:

> I'm challenging myself at this moment. Actually, I think that if we precisely taught the child how to learn, in other words if we really taught true mathematics, the child would be in a position to solve test questions when we asked. But yes, the ability to solve tests improves, but the child can nevertheless feel that it is something he or she can do when the child sees the test for the first time if we teach well. I think there is still something in our method of teaching which I cannot precisely cover related to mathematics or numbers; it may be something to do with the child or with us, but there is still some sort of shortcoming.

Merve’s comment about the nature of the mathematics reveals her own understanding in rediscovering her philosophy of teaching these disciplines. It can be seen in her statement that Merve was aware that relational mathematics is a subset of the instrumental mathematics. On the other hand, she thinks that if they could teach instrumental mathematics, students would do better in tests. She inquired why they couldn’t teach instrumental. According to Merve, there might be two reasons behind this. There may be a

shortcoming in their teaching related to the system, or there might be something to do with students' backgrounds.

When I asked them how we could teach to the students without hearing them "Why do we need to learn this?", Merve's answer implied that students' learning affects permanency positively when they receive instruction in their usual way of learning. During the professional development meeting, Merve elaborated on the notion of making content tangible to pupils:

> I am pondering myself. All I remember about science lesson is for example when we were examining the structure of a cell, presumably while we were freshman at university. The lecturer got us to make a cell model out of gel. That is to say, I never remember anything as if I had never seen anything related to science up to that time. This lack of memory implies to me that I learn through such things, or such things remain in my mind. It is as if that was the only lesson, I received about science all through my life, but in fact there was a long process before that. I don't remember any of it.

In terms of the nature of the engineering and technology, it is important to keep in mind that during her undergraduate years, engineering and technology content knowledge or technological pedagogical knowledge was not a part of the curriculum. Therefore, all of her experience with teaching engineering and technology has developed during her professional years with her own effort. Analysis of transcripts of the professional development meetings revealed Merve's understanding of the nature of engineering and technology.

According to Merve, engineering discipline is about producing prototypes and engineering design cycle. When producing prototypes, it is important to use recyclable and easily accessible materials and to make improvements on the design in line with feedback. Yet, one may infer that there is still room for her to develop her subject knowledge and pedagogical content knowledge of engineering. She expressed her lack of self-efficacy beliefs in teaching engineering.

Secondly, she thinks technology doesn't necessarily mean electronic gadgets; instead, thinking skills such as critical thinking, analytical thinking and questioning are included in

her notion of technology. Her initial ideas regarding the nature of technology consisted of electronic devices and designing and creating 3D printouts. Later, she attended a professional development course and her understanding changed in a way that was inclusive of thinking skills. Merve stated that she could not receive an education in line with her views on the nature of the technology discipline during the professional development course she attended before this research. According to Merve, with the developments in the technology discipline today, the materials used should be included and information about them should be taught. However, during this course, her views changed, and she started to think that concepts such as reasoning skills, different thinking and imagination can also be seen within the scope of technology discipline.

In summary, Merve's comments during the interviews and professional development meetings provide significant insights into what she believed about the nature of mathematics and science. At the beginning of the research, while Merve viewed the discipline of mathematics more as relational, she developed new beliefs about the fact that this discipline was instrumental during this research. With this change, Merve categorizes mathematics into school mathematics and real mathematics. She believes instrumental mathematics is more exclusive than relational mathematics. Engineering discipline consists of designing and building tangible prototype. And lastly, technology means both knowledge of electronic devices and thinking skills.

4.1.1.1.3. Beliefs About Context

This section analyzes Merve's contextual knowledge under five subsections. These are: country conditions, community, school, student, and teacher context.

Data analysis demonstrated that her available opportunities didn't have the conditions necessary for her to carry out attractive teaching. The existing education system was also among the factors that she believed would prevent efficient STEM education. There was also the lack of support to public school teachers as regards professional development, the intensity of the curriculum, the lack of family support and physical drawbacks at school. On the other hand, Merve believes that the implementation of integrated STEM model will positively contribute to her students cognitively, socially, and emotionally as well as to the professional development of teachers.

The impact of conditions of country component was investigated first regarding contextual knowledge. The analysis of the interviews and professional development meeting transcripts has revealed that there are several elements that can be viewed under the country conditions. First, professional development is not given enough importance. Second, the curriculum is overloaded. And third, Turkish educational system is insufficient to put the innovations in the field into action.

Merve explains that even if it is important to develop herself in her field as an elementary school teacher in a public school, professional development is underrated for public school teachers with the current education system in Turkey in contrast to private school teachers. There are several reasons behind that. First, neither government nor schools provide any funds to cover training costs. Second, since professional development courses are not part of teacher evaluations, they are not distinguishable in education at all. She explains her inner motivation to attend a course in her words: “You know, as I said, you know a lot, something, but I wanted to see whether I knew it right.”, and she had external motivation to attend to a course because she wanted to have a certificate that shows her competence in integrated STEM education. She explained as:

> Well, it's sometimes important to have a document at hand in Turkey. Instead of leading other people to say that she is shooting from the hip, it was important for me to have such a document and to be able to say, “yes I have received this education”. For this reason, even the other participants attending from private schools were very surprised with us, because most of them didn't pay any money as course fee; either their schools paid for the fee, but according to the instructor of the course and the other participants, we don't actually need such a thing at a public school at all.

According to Merve, on the other hand, students are exposed to an overloaded curriculum in the current curriculum, especially at their given age. Merve thinks teaching with integrated STEM education would be very beneficial in Turkey. According to her, it is because the current curriculum contains unnecessary standards. Besides, integrated STEM curriculum may give the students the experiential learning opportunity and help them to be more successful. According to Merve, curriculum is overloaded and based on memorizing. Merve believes through integrated STEM students.

Lastly, during the professional development course, while Naz was criticizing the way the Ministry of Education put into force a former project named “Fatih Project”, Merve stated that the Ministry of Education’s preparation for enacting new methods or projects are not effective. She thinks the government put into action an innovation in education without infrastructure, professional development, and planning. She stated that:

> Well, we now have such a system, for example “Fatih Project”, they initiated it in excitement. You're leaving. You don't put it in a system, you don't prepare the teacher, you don't prepare the technological conditions, you don't prepare the student, but you're doing something. (…) Just for the sake of having done it. Also, you waste your money. For example, children cannot now even use the tablets given to them. Since you cannot load anything on the tablet.

Regarding the beliefs about community, Merve thinks that families’ support is missing in the inquiry process of students. She explains during focus group interview why she thinks that way with an example from one of her former projects. In this project, she planned to ask open-ended questions that require wondering, doing research, collecting data, questioning, and making deductions. In this way, she hoped that students would be active participants of the solving problems in science. However, families did homework for their children instead of supporting them to figure out by themselves. Merve explains her disappointment in the following way:

> (…) For example, I started this class for the first time, how to project my mind, that's to say, I will ask the children a question; and the children will come to me with the correct answer after inquiring it. The first question was: I am wondering how and why the bread rises. Right? They go to their mothers and write everything down. You know, their questioning and investigating. I was imagining that they would go to a bakery and see; make donuts together and they would watch it. They go to their mothers and say it happens this or that way. Then it is completely pointless. Instead of supporting them, mothers make it for them.

Furthermore, while Naz was talking about the missing family support, Merve agreed with Naz and said that family support was also missing whenever they asked for materials from them. Yet, Merve questioned teachers’ methods to communicate with parents while

Zeynep was talking about it. She asked if they explained the benefits of their new methods, families might be more supportive. It can be seen in this section:

> Zeynep: Parents think that proper education is not conducted through activities. That is to say, they question whether the activity will contribute a lot to the child; did I explain it correctly? In other words, you know, if you can tell the parents that the activity will actually turn into education, I mean, if you can talk about it the parent himself or herself, the parent says okay and accepts it, but otherwise, there are those who see it as a waste of time, quite the opposite.
>
> Merve: If we know how to present properly, like the one yesterday, for example, the child did the addition in this way this is something really good perhaps we fail to show it to the family.

About the school, in the interview, a central belief of Merve was that integrated STEM education in general is lack of technology in her school. She believed technology is an important component, yet their limited access to technology in their school prohibits her from applying a curriculum she planned.

> Well, for instance, the target would be for their children to build a bridge… the children really design a bridge on the computer… they really make a prototype off the bridge they imagined and construct that bridge in harmony with that prototype with the help of a program, and to make a trial of it, they try it by turning it into a reality. …they carry out trials with weight… but we never went through these processes… Because there is no such at field in which we can conduct education through computers or tablets, but if they are used, the results would be very fine.

When I asked her about this limited access to technology, how she could use it best, she answered her students were only able to use search engines to research. The next episode between Merve and me shows the details:

> R: All right, for example, what, well, how would you use technology now if you wanted to do STEM when such impossibilities exist?
>
> Merve: We tried to do such an activity for an event the previous day. Well, I wanted the students to make a strong tower from spaghetti. I could have made the materials

simpler. And when I think about the circumstances I am in, all I can do is to enable them to search on the internet.

The analysis of the student component shows that Merve has several ideas about the roles of students in her teaching. Pre-interview and transcript of professional development meetings have been used to analyze her beliefs regarding students.

Her beliefs about the student component can be examined under six subdivisions. First, her former applications revealed that there were differences between different age groups. Second, group studies are an important part of the integrated STEM education, and depending on this, students were able to develop their 21st century skills such as collaboration, clear communication, and creativity. Third, students' self-confidence could improve if they had a chance to express themselves. Forth, children have a wide imagination, and it helps them to create nice designs if an opportunity is given. Fifth, she believed students might develop positive science and mathematics identity with integrated STEM education. Sixth, during integrated STEM education, students should be learning in groups. However, according to her, not all students may benefit from group studies if they cannot participate equally because of power dynamics between students.

The analysis of Merve's belief about the student context starts with the investigation of her beliefs regarding different grades of students. She believed that working with fourth grade students was more efficient than working with first graders because of their readiness issues.

Second, Merve believed that group study was a sine qua non condition of integrated STEM education and with group studies, students become better problem solvers, better communicators and more productive. She said: "In terms of children, it is something which will improve their self-confidence, … express themselves more comfortably (…) I mean joint decision making, for something, coming together for the same purpose(...) Well, it is nice to provide it.".

Third, Merve believed that students might have a chance to improve their self-confidence in integrated STEM education. Her belief comes from one of her experiences with students (Fourth graders). Merve took her students to a conference, and at that conference each of her students was responsible for a group of participants. Merve made

participants carry out a STEM activity that her students were also familiar with. At the end of the session, Merve's students answered participants' questions about STEM education. During this conference, Merve had a chance to observe her students more closely. She indicated that the integrated STEM education enhanced her beliefs about her students' self-confidence:

> I observed that children's self-confidence really increased enormously… Later, a project we made about it was chosen as a good project by the Ministry of Education… the way they cherished the project, they told people about STEM. As a matter of fact, they started to tell the provincial Director of National Education about something they had just heard, like what is STEM? … it was so good for them to see it and to try to tell other people about it with self-confidence.

Forth, Merve believed children had a wide imagination and this had a positive effect on designing and creating a product. In contrast, grown-ups have fixed mindsets regarding the problem solving. Merve's beliefs about students' wide imagination and open mind can be seen in her statement:

> I saw that, unlike grown-ups, children could make very different and diverse designs. … children could produce much better products, in design. … they can come up with more creative products, … they have more flexible borders and they come up with better designs and they feel entertained during this process.

Fifth, after two-month-long STEM activities, she observed that her students started to develop positive identity regarding science and mathematics. She made this deduction from her observations. She observed that her students started to call themselves with scientists' names, and in their spare times, they were talking about inventing new things and becoming a scientist in the future. Her beliefs regarding student context come from her these observations. Therefore, she believed students might develop positive identity towards science and mathematics after the implementation of integrated STEM education. She indicated this idea as follows:

> (…) In the conversations we made after those STEM activities, it's very difficult to hear such an expression as I would be a scientist when I grow up or I'll be a scientist.... They generally replied that they will be nurses or doctors and the like.

> You know, we saw at the end of this process that even their career choice became different (E: Um), and that they started to motivate themselves by saying yes, I could be a scientist because I made an invention.

Sixth, she believed that group studies were not easy to employ yet necessary in elementary grades. She believed that because of the power dynamics in group studies, some of the students might not take advantage of this method. She indicated this idea as:" (…) Actually, some drawbacks may perhaps arise for children when proper distribution cannot be made in groups. Children who feel inferior or excluded by the group may feel bad because of the process.".

For Merve, elementary school teachers make connections between disciplines in most of the classes. She also implied that during the lesson a teacher might change the direction of the classes. Because of these reasons, she believed that integrated STEM education should start from the elementary grades.

> First, being a elementary teacher is already at complete thing, actually when you enter the class as a elementary teacher and you say that we are doing life sciences, you're not actually just doing life sciences. You may be doing a very different thing. Indeed, I think that STEM should for this very reason start at primary school.

On the other hand, Merve believes students' overall achievement in mathematics and science will determine teachers' decision-making mechanism in assessment and evaluation. To clarify this idea, her conversation with Zeynep is given below:

> Zeynep: A student in Gamze's class, Gamze wrote rhythmic counting in the notebook and said, count from 4 to 40 four by four. However, Gamze wanted them to write on the paper starting from 4. But when she asked for an expression of it, the child left there a blank. The child again counted it silently. Did you understand? Later she calls the student, a successful student; why did you leave this a blank? The child said, my teacher, I didn't leave it a blank, I did it. How so? The child said "Well you told me to count. I counted it by my heart.
>
> Merve: Because the child was a successful student, she asked about it. She wouldn't have asked if the child had been an unsuccessful student.

Lastly, Merve believes that integrated STEM education made her query to find different ways to teach after STEM implementations. She also said that participating in this research made her do research to improve herself. Besides, Merve believes there are two types of teachers: first, teachers who are open to professional development; second, teachers who are not. She said:

> STEM education is also absolutely favorable from teachers' perspective. Of course, it is positive for teachers open to development, it allows you to seek different routes, well, um, to research in order to develop yourself. In other words, it makes you question "I wonder how I can teach this in the classroom" and how you can implement something different in your own class.

4.1.1.2. ***Pedagogical Content Knowledge of Merve***

The results of the analysis of teachers' PCK were presented in nine components with its subcomponents.

As Merve's pedagogical content knowledge in STEM educations examined, it is seen that her knowledge of STEM education improved, which was in turn reflected on her implementation of STEM education. Merve included instructional strategies that will enable students to learn actively in her lessons. These strategies are generally strategies that aim for students to learn cooperatively and improve classroom management. However, using very limited strategies on the subjects (topic specific strategies) cannot provide in-depth learning of STEM disciplines in STEM education and consequently has limited knowledge in this component. The effect of the implementations she conducted in the professional development course within the scope of this research is seen on Merve's instructional strategies that aim to increase student participation. In the modules she designed, Merve chose the learning outcomes to be parallel to the curriculum, and these outcomes generally address different cognitive stages of the students. However, she usually excluded the discipline of technology in her implementations, and it is seen that the underlying reason for this is her lack of knowledge in this discipline and the context they were in. While adverse effects of the conditions of the school and the country are seen on Merve's education, it is observed that her knowledge regarding the student had an effect on shaping her education according to the student. While she included 21st century skills in her lessons, she followed

the learning process of these skills. It is seen that Merve's knowledge of what and how to measure in assessment and evaluation increased during the research and she observed students' learning more closely by making formative assessment. In general, we see that Merve adopts the context integration model in STEM applications and puts the discipline of mathematics at the center. Merve developed professionally in the following contents during the process of the research: knowledge of assessment, knowledge of teaching strategies, knowledge of students, knowledge of 21st century skills, and knowledge of integration. Besides, it is seen that the professional development course in the research was directed at implementation, it was implemented in the context of teachers' own teaching, the constructivist method was used end the shared resources were useful in developing and the shared resources were useful in developing the STEM module. All of them had a positive effect on Merve's PCK development.

4.1.1.2.1. Knowledge of Teaching Strategies

When Merve's knowledge of subject specific strategies is examined, it is seen that she mostly included the strategies related to mathematics and life science and partly the strategies related to the discipline of engineering. It is observed that she adapted the strategies implemented in the professional development course to her classes and made use of them.

Using these strategies, Merve focused on examining her students' previous knowledge, developing their active and cooperative learning as well as aiming for class management. It is seen that Merve generally made use of word problems rather than authentic questions. It is also seen that, by means of word problems, she aimed to develop their mathematical thinking skills by using the context the students were in. In addition, she included product designs based on learning outcomes in her classes by using engineering design process. However, Merve didn't exactly utilize engineering cycle in these designs, and these designs are far from challenging students.

When the strategies Merve used in the first module are examined, it is seen that during the implementation of the first STEM modules, she used several subject specific strategies. Merve used 3-Act-Modeling method as an overarching method of the first module. She also

used several student-centered teaching strategies. In 3-Act-Tasks, three actions are involved to engage students in modeling. These are:

1. Identifying the problem and posing a question
2. Making an estimate
3. Identifying what variables are needed to solve and answering the problem. (Fletcher, 2016).

Merve designed her first module as a 3-Act task. In the first act, she made her students watch a part of one of their favorite cartoons. She used this video as a context of her module. The reason why she had chosen this cartoon was because, in their Life Sciences unit, the topic was cultural elements, and she used this video as a context of her mathematical problem. After Merve shared the video with her students, she asked them to define two things: first what they noticed, and second what they wondered. She was expecting her students to engage with the context to develop mathematical understanding. Therefore, she used a worksheet she had prepared for students to take notes about what they had noticed and wondered. Then, she asked her students to share their findings with the whole class. With the students, they decided a question to answer and make estimations about the likely solution. Then, Merve guided students' curiosity to a point that she would like to discuss with her students. She asked her students this question: "In what ways can we use the word 'split'?" She used another strategy, which is "Think-Pair-Share". Her students discovered the meaning of split. Then, she used another strategy, which is "creative brainstorming with post-its". She asked her students to write their ideas on the sticky notes and share them on the blackboard. Then, with the help of her students, Merve grouped those ideas and featured the meaning of "split" word. She also emphasized the relationship between splitting and division.

During the Act Two, she posed her word problem. "You are in Sultanahmet Square, and your classmates are fighting with this danger. You want to save the Topkapi Palace, Hagia Sophia Museum, and Basilica Cistern. How many of your classmates should go to each place?" And she asked her students to estimate and note those estimations and reasonings on their worksheet. She formed them into groups and asked them to figure out what different

methods they might find. She then introduced ‘microphone method’ to her students. This is a method that each student must share at least one idea. To share their idea, they need to hold to a microphone, and all the other group members need to listen. Then, she asked a group member to share their solving strategies.

With the whole class, Merve compared their solutions with each other’s. Then, Merve made her students compare their solutions to their estimates and discuss the comparison. In this final stage of 3 Act Task, Merve asked her students to show the difference between their estimations and answer by using their body language. Merve coded these differences and asked each student to use the signs accordingly.

In this strategy, on one hand, the teacher showed how she valued several problem-solving approaches; on the other hand, the teacher expected her students to understand similarities and differences between solutions. Therefore, the teacher created a learning environment for students to develop their higher order skills. According to Bloom taxonomy, drawing connections between ideas corresponds to the level 4 basis of six cognitive processes. Most importantly, Merve wants her students to have the strategies; therefore, she showed how willing she was to share the agency with her students in her classroom.

In the 3rd lesson of the first modules, she employed another 3-Act-Task in division topic. On the last act, she used ‘small group studies” and ‘station rotation technique’ to make her students share their solutions with each other. She also used small group discussions to promote several solutions to a mathematics problem.

In the second module, she used several strategies, such as small group discussion and engineering design process. In this module, science topic was manufacturing and industry. Merve used small group discussion method to reveal her students’ prior knowledge in this topic. Then, she applied engineering design process in her class. In this part, she gave her students a worksheet that she prepared prior to the lesson. Students imagined and designed a toy. And each group presented their findings and studies to the whole classroom. In addition, Merve asked her students to give a name to their group. In this way, her students’ state of belonging might have developed positively.

In the third module, Merve used several subject specific techniques such as Concrete to Representational to Abstract (C-R-A) Instruction, design thinking, group working. She first used independent studying. The learning outcomes for this sequence are: (1) Students observe industrial manufacturing activities in their local district. (2) Students will be aware of career information about the many fields in manufacturing. Merve asked her students "What profession would you be you think if you were doing this toys' design?" and "How could you design a toy if you would have these materials?" Then she gave her students a worksheet to study independently.

Second, she stated that she applied engineering design technique. In her lesson plan, design thinking has a role of teaching how engineers think. Also, by designing a concrete material, she aimed to model division problem. Then, she transformed concrete material into a representation of division problem. Then she moved from representational level to abstract level.

She used a worksheet during the implementation of design thinking sequence. She also grouped students to create their designs. Since the topic of the module was manufacturing, Merve aimed her students to grasp the idea of designing. She assigned her students to design a toy. After each group designed their toy, a student from each group presented their designs. Merve also asked her students to explain in what ways they designed the toys and how they used their materials. However, the lesson was composed of a mathematical activity even if it was referred to as an engineering design activity. The lesson did not include elements of an engineering design cycle; instead, it involved designing materials using concrete objects to show solutions to the mathematics problem.

In the fourth module, Merve used several subject specific strategies such as independent learning, design thinking and direct modeling. In this module, Merve designed lessons as her students worked independently. Students individually colored a map of Turkey and a map of Marmara region (in which the school is located) and Istanbul (in which students are located). Then students designed a map by using these maps.

Then Merve posed a word problem in which she was expecting her students to solve "26: 4" question. Merve posed this word problem because in the former lesson students had been introduced to dividing without remainder. Merve used direct modeling in this section

of the module. Then Merve used the whole group discussion strategy to examine different types of solutions to the problem.

During the fifth module, Merve used problem solving skills in real life context activity, group study, Think-Pair-Share strategy, and a mind map as well as brainstorm techniques. First, Merve created a story that introduced the idea of how to patiently take care of plants. Then, Merve created a mind map with the whole class by doing brainstorm based on the story. Then, she gave a test which included open-ended problems related to the story. Later, she gave each group several solid geometric shapes. Students worked as a group to find the similar and different attributes of geometric shapes. Then by using the Think-Pair-Share strategy, the whole class discussed the attributes of geometric shapes.

During the sixth module, she used independent learning, group study, hands on activity, and creating design strategies. Merve created context for the module by using a story. She read the beginning of the "Jim and the Beanstalk" story. Then she paused and asked students how this story might end. After a whole group discussion, Merve gave time for students to design a prototype of a building by using geometric shapes individually. Then, she grouped students to create their designs. As students created their designs, Merve gave each group recyclable boxes and other materials such as glue, crayons, papers, a ruler, and scissors. After each group designed their materials, the tallest building, a student from each group presented their designs and their reasoning to the whole classroom.

In summary, the subject specific strategies she used show that Merve aimed at efficient learning in her class. However, word problems or design challenges which she employed were far from challenging her students cognitively. This is because the teachers chose easier problems compared with their levels, their lack of engineering knowledge and their lack of access to the required materials.

It can be seen that Merve adopted several strategies from our professional development course. These strategies helped her to organize content into an effective and collaborative teaching sequence. Additionally, with these strategies, Merve was able to use effective classroom communication.

Merve frequently used concrete materials as well in her lessons. While Merve's initial intention was to create environments for her students to use the cycle of engineering, it is seen that she used concrete materials to make them create design related to theme of the classes throughout the implementation process. Problem solving processes with concrete materials enabled the students to use the outcomes they learnt during classes.

Regarding to topic specific strategies during the first modules, Merve used two representations in the learning of division. These were arrays and number lines. After her students designed toys by using the plastic water bottle caps, Merve asked her students to show mathematical thinking in their design on a worksheet. Merve gave 20 plastic water bottle caps to each group.

At first, Merve used arrays and provided a picture of the ways in which 20 can be shown as 4 x 5. She arranged 20 in rows and columns such that every row was the same length, and every column was the same height. Second, Merve used skip counting backward strategy while using repeated subtraction to solve the division problem. And she used number line while she was explaining one of the groups' solutions to whole classroom.

4.1.1.2.2. Knowledge of Curriculum

Merve's knowledge of curriculum related to topics she included in her STEM lesson plans was investigated. Merve's knowledge of curriculum about topics she included was evaluated with the help of professional development meetings, lesson plans, classroom observations, interviews, and her reflections.

The interviews made with Merve have revealed that she updates the changes made in the curriculum during the periods of seminars organized at the beginning of each term in their school. When the data obtained from the process of the preparation of lesson plans are examined, it is seen that she had a good command of the outcomes in the curriculum. when the outcomes she included in the lesson plans are examined, it is observed that she integrated in the disciplines of Science and Mathematics the outcomes which would activate different cognitive stages of her students. However, it is viewed that, because an instructional program at the level at which Merve conducted teaching was nonexistent in the syllabus of the Ministry of Education related to the discipline of engineering, she obtained the outcomes

regarding this class from online sources which she herself found. It is also observed in the engineering outcomes she included in lesson plans that she brought forth the outcomes which would improve cooperative learning processes (team work, problem solving, etc.) and the outcomes related to mathematics

Another important finding regarding Merve's knowledge of the curriculum is that she did not include the outcomes of the discipline of Technology while designing lesson plans. No learning outcomes were present designed by the Ministry of Education at the grade at which was teaching. The main reason why Merve excluded learning outcomes related to the discipline of Technology is that she thought there was no possibility for her to implement them in the school and the classroom where she worked. Another reason is that she didn't have enough content knowledge about technology. More specifically, Merve stated that while she was attending university, lessons related to this field were not included in her schedule and expressed that she had never participated in any process of education in this field throughout her professional career.

On the other hand, the interviews made with Merve have revealed that Merve chose the learning outcomes in parallel with the curriculum. She remarked that developing STEM modules in parallel with the curriculum prevented lessons from being more efficient in most cases and that it restricted the lesson plans she was making. At this point, we see the effects of the implementation of the curriculum in Turkey. In Turkey, teachers have to cover specified units in a given time and Merve tried to fulfil the obligation the learning outcomes in this given period of time.

4.1.1.2.3. Knowledge of Student

In this section, the requirements of students for learning upcoming STEM module, and students' conceptions, as well as learning difficulties were presented. Merve's knowledge of students' requirements for learning was evaluated with the help of interviews and lesson plans and teachers' reflection papers.

Studies have shown that Merve was conscious of her students' interests. She took advantage of student interests to motivate students to the subject they would learn by associating with learning outcomes. On the other hand, Merve knew her students' previous

learning and built her new STEM lesson plans on her students' previous learning. In addition, within the scope of this research, we see that Merve developed new insights in the field of knowledge of student. Merve emphasized that in this new model she implemented, all of her students, including those who had been passive observers in her previous lessons, actively participated in the lesson. Merve also stated that she could observe her students' learning more closely in this study because she used formative assessment tools. As an effect of this, Merve used written and verbal assessment and evaluation methods and stated that she saw her students' verbal skills more developed than their written skills.

Merve emphasized what students needed to know prior to her first STEM modules. According to Merve, children would be interested in watching this cartoon, because as she observed her students, this was one of their favorite cartoons. Also, Merve stated that students need to learn about cultural heritage sites within the scope of the current curriculum.

> Istanbul Muhafızlari was chosen because it is a popular cartoon among children. Since they could not visit our cultural heritage items, they started with this topic, starting from the context of what they had seen and heard there many times.

While her students didn’t have any opportunity to discover them in person, she figured out using technology might be useful to teach this topic. On the other hand, she stated that since her students knew how to group and skip counting, she could start with an example of skip counting by 2 and grouping by 2. She stated in her reflective journals that: “Because the children knew how to group and count rhythmically from last year, we started with the example of grouping in pairs.”

At the end of the research, Merve observed that during STEM practices, students who did not actively participate in their traditional lessons and did not express themselves successfully participated in the activities and comprehended the content correctly. She even stated that although these students could not find some mathematical solutions in traditional lessons, they found them during their STEM practices and expressed them orally.

On the other hand, during the STEM practices, Merve used formative assessment methods,and, in this process, she orally evaluated the students' learning in some courses. Using formative assessment helped Merve better understand students' learning. In addition,

Merve observed that during the STEM applications, her students expressed better verbally the information that they could not express in the written exams and stated that she saw that only the written assessment of the students was insufficient to correctly understand the development of the students. During these observations, Merve also stated that she discovered that her students' reading comprehension skills also greatly affected their success in other courses.

4.1.1.2.4. Knowledge of Assessment

Merve's knowledge of assessment is analyzed in this section. The data have revealed that there were differences before and after researchers' professional development course. It is seen that, before the research, Merve thought that it was not necessary to measure the learning outcomes in STEM education as an effect of her perceptions about STEM education. It is also seen that Merve's knowledge of assessment and evaluation tools was also lacking. During this research, Merve developed her knowledge of formative assessment tools and what and how to assess, and benefited from this knowledge, which she also developed in STEM education applications. In addition, Merve stated that she could follow the cognitive development of her students more closely by using formative assessment and developed an understanding that using only written exams didn't not measure the student's learning completely.

Before the implementation of the professional development course, in initial interviews, Merve expressed that she valued assessing students' 21st century skills such as communication skills, collaboration skills and testing endurance of the designed material.

> For me, it's like getting students to become used to group work and getting them to work together and trying to teach them to like and appreciate what someone else is doing. Actually, the thing I care about most (…) is the process, at work, ıı, being able to work together, producing a product, being able to express it correctly, being able to describe it… I mean, measuring such things (…)

Initial interviews also revealed that Merve's knowledge about the terms, definitions and scopes of the assessment tools, in this case formative assessment tools such as rubric and

peer assessment and observation, were limited. The next episode of the interviews will explain this as such:

> Merve: (…) when they [the students] evaluate groups at work according to the criteria, they can evaluate groups outside their own group. Well, I give it four out of five; because, like (…) We can also examine the activities we do with something like an observation form, by taking notes, the relations of children with each other, and see if everyone can express themselves.

According to Merve's initial perception of STEM education, the assessment of the standards was not involved in assessing process. She criticized herself by saying that maybe she had never had a chance to connect STEM activities with standards. "Perhaps that was one of the things I misunderstood in STEM education so far. I never knew that STEM education would be used to measure course achievements.".

We focused on teaching and assessing STEM subjects in an integrated way and related to students' lives during the professional development course. The professional development meetings were designed on the definition of integrated STEM, which focuses on teaching STEM subjects integrated with each other and with students' lives, student-centered while using more effective and rigorous teaching methods. Objectives might come from current curricula or a set of research-based, up-to-date K–12 science standards such as NGSS or ISTE standards. Accordingly, she prepared her lesson plans that were able to connect current curriculum with more effective teaching methods. While designing her lesson plans, Merve took advantage of the learning outcomes in the current curriculum and included appropriate assessment and evaluation tools in the lessons in line with the objectives of the lessons. Along with that, she started to use assessment tools which might help her to understand student thinking better and help her students to improve their self-assessments.

During our research, it is observed that as teachers prepared their own integrated STEM modules Merve developed her knowledge of assessment in two ways: first she improved her knowledge of what to assess, and second, she improved how to assess learning.

This improvement can be seen in her lesson plans and observation of classes. For example, in her first lesson plan, she developed and planned to use 'Formative Assessment

Notebook' throughout the STEM implementation. Also, she used the method we applied in the professional development course such as think-pair-share, creative brainstorming with post its, using body language to show the answer, station rotation technique. As well as these formative assessment tools, she decided to create portfolios for each student; in this way, she was planning to capture a richer array of what students knew and what they could do, also to portray student improvement. Along with them, she was encouraging her students to actively engage with the content. 'Formative Assessment Notebook' can be seen in the image captured from Merve's lesson plan below (see figure 4.1).

Formative Assessment Notebook	
What did you realize?	What were you curious about?
What is your guess?	What is your solution?
What is the most valued solution in the group?	What different materials did you think you could solve?
What is the relationship between your prediction and the actual result?	Write the name of the historical artifacts you saw during the lesson.

Figure 4.1 An Imaged Shows the Assessment Tool Captured from Merve's Lesson Plan

In her first module, she also created a rubric with which to evaluate students' collaborative learning and communication skills. This rubric can be seen in the image captured from her lesson plan below (see figure 4.2).

Figure 4.2 A Rubric Created by the Participant Teacher

Name and Surname: **The Aforementioned Project: Student seeks a solution to life-based learning problem**				
	6-5	4-3	2-1	Score
Understanding	The student fully understands the purpose of the assignment	Partially understands	The student did not understand the purpose of the assignment	
Group dynamics	The student shares to discuss the process and inform other members	The student does not share with the other students	The student is not aware of the work of the rest of the team	
Behavior	The student listens to the ideas of his or her teammates	The students did not provide enough useful contribution to teammates who needed help	The student works alone. Did not help others.	

On the other hand, with the aim of monitoring students learning, Merve designed a worksheet named “About the Study”, which consists of 4 open-ended questions. Merve used this worksheet as an assessment of students’ metacognition and the evaluation of the implemented STEM modules. Here, we also see that Merve examines the students' individual views on group work. After each module, Merve evaluated the responses of the students and designed her upcoming modules accordingly. “About the Study” worksheet can be seen in the image captured from her lesson plan (see Figure 4.3).

Figure 4.3 A Worksheet Created by Participant Teacher

Merve designed an open-ended problem-solving activity and used open ended questions for the assessment of the fifth module. At the beginning of the module, Merve read the story that she had created. After reading it, Merve did a brainstorm with the whole class about the main idea and the details that supported the main idea of the story. Then, she gave the problem-solving skills in real life context activity worksheet to the students and each student answered the questions individually. Problem-solving skills in real life content activity worksheet can be seen in the image captured from her lesson plan below (see Figure 4.4).

Figure 4.4 Formative Assessment Tool Designed by Participant Teacher

Flower Care

Deniz bought orchid flowers as a gift for her mother on Mother's Day (first week of May). The florist gave Deniz a care manual about the care of the orchid flower. The maintenance manual contains the following information:

-Orchid flower dries in a dark room as it does not want direct sun. The sun should not come directly to the flower.

- It should be kept in a place at room temperature.

Measures should be taken to protect the orchid plant, which is easily affected by the wind, from this effect.

- The flower should be watered with half a liter of water every 2 weeks in cold months (January, February, March, October, November, and December). In warmer months (April, May, June, July, August, September) it should be watered once a week with half a liter of water.

-The water in which the flower is watered should be at room temperature.

Deniz, from the moment she bought the flower from the florist, has done what needs to be done for the care of the flower. But two weeks later, the original flowers of the orchid dried up and fell off.

Daily Life Problem Solving Skills Test

Question 1: Deniz wondered why the flower withered and wanted to reconsider her actions. Check the processes of Deniz and decide whether it will dry or not.

	Deniz's actions	It blooms (positive for flower)	The flower dries up (negative for the flower)
1a	When buying from the florist, a bag was placed on the flower to prevent it from being affected by the wind.		
1b	Tap water (cold than room temperature) was used while watering the flower.		
1c	The temperature of the room where the flower is located is 15 degrees.		

Question 2: What are your suggestions for the actions (negative statements about the flower) that you think Deniz did wrong in the table above, in order to prevent the flower from drying out?

Question 3: Considering the month Deniz received the flower, how often should Deniz water the flower?

As can be seen, Merve created an assessment tool to assess students' reading and listening comprehension skills. Additionally, Merve used open ended questions to assess students' knowledge about geometric shapes at the end of the module. These questions mostly addressed the definition of the geometric shapes and can be answered with the remembering and recalling skills and abilities except that one question required inquiry. These questions can be seen below:

1. What is the geometric shape with three sides and three vertices?
2. What are the properties of a square?
3. What are the properties of a rectangle?
4. What are the features that distinguish square and rectangle from each other?

What are the features of the closed disc?

In summary, while Merve's knowledge of assessment and evaluation in general and the role of assessment in STEM education were limited before the research, her knowledge in these two areas developed during the research and this change was also reflected in her practices. She stated that she could understand her students' learning more deeply by using formative assessment tools after their implementation.

4.1.1.2.5. Knowledge of Context

Merve's knowledge of context appears as an effective component in the planning and implementation of Merve's lessons. While the information about the context of the student played a role in Merve's organization of her teaching in relation to the students' lives (background), the information about the school and country conditions had a negative impact on Merve's design and implementation of an effective education. Due to the knowledge of context at school and country level, Merve thought that she would have insufficient opportunities in materials, physical environment, and technology, and designed her lessons with limited materials and technology. Since she thought that the active participation of the students' families was not possible, she designed an education in such a way that the families would not be involved in the education. She also stated that choosing course outcomes in parallel with the compulsory curriculum prevented her from preparing more effective lesson

plans. It is seen that the knowledge of the context at the student level played a role in her teaching by taking into account the interests of children, the cultural and social environment they lived in, and the socio-economic conditions of the environment they lived in. She also planned her lessons by considering the current events experienced by the students. As a part of this research, Merve planned her lessons to implement in her own classroom. In general, Merve used her knowledge of context with regard to the school and country conditions to create lesson plans. Merve considered that her school lacked laboratories and the classes lacked materials. Therefore, she limited her use of manipulatives, and she used recyclable materials, also she benefitted from technology only in monitoring videos and images.

Merve knew from her past experiences with families that her students would not be able to access to educational support at home, and therefore she planned all of her lessons in a way to be implemented only in classroom. She didn't create homework or learning opportunities that required family support. During the planning stage, Merve used her knowledge of the context to make her lessons relevant to her students' lives. She also focused on group studies as she thinks students learn in groups more effective. Also, Merve used her knowledge of context in regard to conditions of country. She integrated her lesson plans to the current curriculum. She followed the mandatory curriculum to decide on which standards to include her lesson plans.

I will explain Merve's knowledge of the context in some details as in her lesson plans. In the first module, Merve had chosen cultural elements of Istanbul as a topic, and she started her lesson by showing a part of a cartoon named "Istanbul Muhafizlari". In her reflective journal, she reported that her reasoning was because of students' current socioeconomical conditions they were not able to visit cultural sites and students liked this cartoon. Consequently, she had chosen this cartoon to start her lesson.

She used group studies as the main strategy in this module. Her aim was to evaluate students' communication skills. Accordingly, she created a rubric to assess students' working habits and communication skills.

In the second and third module, she used the context of the city in which they lived. Her lesson plan was based on the fact that Istanbul is an industrial city. She aimed at her students finding out that the vast majority of production activities are carried out in Istanbul. Also,

she aimed at her students learning about careers related to the STEM field. She used her knowledge of the context by means of community; that being said, she aimed to develop low-income students' career interest in STEM-related jobs. Specifically, she focused on engineering. In these modules as well as in the first module, her main strategy was group studies.

In the fourth module, Merve provided ways for students to maintain their cultural identity while she also developed her students academically. She intended to make the lesson plan more relevant to students; therefore, she made connections between their cultural backgrounds. In order to make lessons relevant to the learners, Merve focused on Istanbul's geographical features. She started her lesson by introducing the Ottoman-Turkish admiral, geographer and cartographer Piri Reis and the map of the world he created in 1513. Then, she drew attention to the mathematical skills required in cartography such as scaling, coordinate systems and map projection. Students designed their 3D maps of Turkey, which included the city they were living in.

In the fifth and sixth modules, she covered her lessons on the theme of the annual holiday, in particular, Mother's Day, relevant to her students' lives and the current issues in their lives.

To summarize, Merve benefitted from several components of her students' lives to make lesson plans relevant to her students. She observed her students and planned her lessons accordingly. Meanwhile, she also improved her implementation as she built on her students' body of knowledge and culture to create more intellectually educational experiences.

4.1.1.2.6. Knowledge of Technology Integration

Merve did not formally take a course on technology and its teaching, as there was no course related to the teaching of technology at the university during the years when Merve received her university education. Merve's knowledge in the field of technology has developed through her own efforts during her profession. It is seen that Merve didn't include the learning outcomes related to the technology discipline in the lessons she was planning, and it is also seen that she made use of technology passively in her lessons. In the presentation of information with her passive discourse, technological tools, such as

computers, are often mentioned. In addition, in this study, participating teachers were encouraged to use technology to increase their active participation. Therefore, like other teachers, Merve also benefited from technology to collaborate with other colleagues and researchers in her professional development process. In addition, she used her technology knowledge and developed it in the process of developing lesson plans and in the process of reflecting on their practices.

According to the data analysis of Merve's lesson plans and the observation of lessons, Merve used technology in her integrated STEM lesson in three ways: first, developing her lesson plans by making use of Word, Web browsers, etc. second, she used technology to communicate and collaborate with her colleagues. This practice was created and supported by the researcher as a part of this research, and third, she used technology during her lessons for her students to build knowledge by means of viewing images and seeing a video.

In her first lesson plan, Merve supported her teaching with technology in a way her students watched a videoclip. Her choice of using technology was showing the video clip as a context for the mathematical problem. The video clip also served her students to talk about real life situations related to the current topic in the classroom. Therefore, she used technology for her students to identify a mathematical problem. Furthermore, Merve used technology to show her students the images of the maps created by Piri Reis, and the images of geometric shapes. Consequently, the students examined the images by discussing their thoughts about the visuals.

On the other hand, as a part of our study, I asked teachers to use dropbox and google drive to collaborate with each other. Since this study took 6 months, and included a professional development course, we had to collect a lot of data (video recordings, audio recordings). Therefore, I wanted to keep all of the documents and recourses available to the teachers. Teachers uploaded all the documents related to their lessons, such as lesson plans, reflective journals, audio and video recordings of their lessons. Therefore, Merve used technology to collaborate with her colleagues and reflect it to her own teaching.

It is also observed that Merve used technology to create her lesson plans and assessment tools. She used the online sources which the researcher supplied. Additionally, she used

Microsoft Word to create her lesson plans and assessment tools such as formative assessment notebook, the study worksheet, and rubrics.

4.1.1.2.7. Integrative Thinking

Integrated STEM education is a developing area in education and different approaches are defined by scholars. These approaches are content integration and context integration (Stohlmann et al., 2013; Roehrig et al., 2012). Content integration is a way to focus on the combining the several content fields by emphasizing the big ideas from each content areas. Context integration is a way to center one content area and teach it effectively while utilizing the other content areas as context.

The analysis of lesson plans and reflective journals revealed Merve's choice of integration model. Merve designed integrated STEM modules as context integration. She centered mathematics and she used the context from Life Sciences, Technology and Engineering disciplines. For example, Merve made students watch a videoclip from a cartoon about historical heritages in Istanbul. Then, Merve asked students about several methods to solve a dividing problem. Then, Merve asked them to design a 5-story and 20-room museum. She challenged her students by giving a dividing problem as each story had 5 rooms, and each story was themed with different cultural elements. Merve divided students into groups and asked them to think of themselves as civil engineers or architects. While life sciences topics consisted of cultural elements and engineering concepts such as working as a team or constructing a prototype, students did not require the explicit use of life sciences or engineering content to solve the problem.

4.1.1.2.8. Professional Growth

Merve's professional growth was analyzed by using the data from interviews and documents such as reflective journals and her resume, and transcripts of professional development meetings.

Professional development course seems to have enabled Merve to develop her pedagogical content knowledge, her own 21st century skills such as collaboration and communication. The analysis of Merve's working developing pedagogical knowledge

indicated that she had developed her pedagogical content knowledge. The areas developed in her pedagogical knowledge are knowledge of assessment, knowledge of teaching strategies, knowledge of students, knowledge of integration and knowledge of 21st century skills. The convenience of the professional development course applied within the scope of the research is another important finding that emerged in the active participation of the participants from the beginning to the end of the research.

As we analyze the data, it can be seen that Merve's knowledge of assessment improved during the research. In contrast to her past perception, she valued assessing student learning in integrated STEM modules. During our initial interviews, Merve revealed that Merve's expectation in STEM education was to attract students' interest in professional groups in STEM disciplines and to enable them to improve themselves in group work. As part of this study, Merve focused on monitoring students' learning in the context of the lesson plans she had created. She also focused on developing assessment tools that helped students to clarify their own learning. During her implementation, she mostly used group studies and she observed her students to guide them. As a result, she had a bigger picture of what students knew, how they learnt. She aligned her assessment approach with the expected learning outcomes. She developed assessment tools that monitored student learning in the learning process. Therefore, she concentrated on providing regular feedback on students' own learning. During our last interview, she emphasized that using only multiple-choice tests or open-ended questions which only allowed students to remember the knowledge was insufficient. She expressed her developing ideas about knowledge of assessment in the following way:

> Actually, I no longer evaluate those children by looking at such things (multiple-choice tests or open-ended questions). Because after seeing what I went through and their efficiency in that group work, I don't get up and grade them just by looking at the written exams.

There is evidence that Merve's knowledge of teaching strategies has improved. She has developed her knowledge and practices as she has implemented student-centered teaching strategies in her STEM modules. Merve used several subject-specific strategies in her integrated STEM modules as part of this research. It can be seen that in her lessons there

were the influences originated in professional development course. These influences can be seen in two forms. First, she applied the strategies that we have been using as a strategy in the professional development course. Second, she used the strategies that we have analyzed by watching videos and had discussion on the possible ways of using them in the classroom. The former category consists of strategies such as brainstorm, mind map, direct modeling, think-pair-share, creative brainstorming with post-its, small group discussions. The latter category consists of 3 act modelling, microphone modeling, guided entire classroom discussion, mathematical modeling.

Data analysis has also revealed that Merve's knowledge of students showed progress during the research. She built her lesson plans on her focus students' current thinking and connected them with it. However, the analysis of her reflective journals has revealed that she constructed valuable knowledge of students by using integrated STEM education in her classroom. She observed her students' learning during the modules. In addition to this, she created Formative Assessment Notebook with the aim of developing her students' self-assessment skills. She discovered that while her students were expressing their knowledge verbally very effectively, they were not able to express their knowledge through writing. Therefore, she thinks that her assessment should rely on both verbal and written sources. As she expressed:

> For instance, one of my students was in the circle group and he really expressed himself, he said that the circle had no corners, and this is its most basic feature. I mean, when a child says this, I would say that there is no stimulus, if he looks from the side while writing, but when he started writing on paper, he could not write, for example, he wrote something very irrelevant. I don't think it had anything to do with the fact that he couldn't answer in the written evaluation. Considering that the entire education system is based on written assessment-evaluation, we actually do not measure students completely.

Second, as Merve observed her students' learning, she came to realize that her students were working more confidently when they studied in groups. She expressed her amazement as follows:

> (…) They loved what they were doing and even wanted to take it home. And I enjoyed the process because they conducted it outside of my thinking. (…) They found methods I had never imagined. I think integrated STEM modules are definitely helpful. They think differently, which triggers each other. So, they make you think differently. …with this method, they at least have the opportunity to share their thoughts with others and see their deficiencies. (…) The child deduced that we could also answer this question with the sequential subtraction method. For me, it was something I did not expect from that boy.

The analyses made reveal that the professional development course in the research contributed to Merve's knowledge of integration. Merve's definition of STEM education at the beginning of the research shows that "the student starting the process where he/she develops his/her reasoning skills in the face of a problem" emphasizes concepts such as problem solving, learning motivation and creativity, but she did not include information about in-depth and conceptual teaching of STEM disciplines in her definition. As part of this research, Merve began to develop an understanding of integrated STEM education as an effective teaching of STEM disciplines.

When the development of Merve's knowledge in the field of 21st century skills is examined, it is seen that the use of such skills as collaborative work and problem solving during her professional development course improved her communication skills. It is also seen that the documents provided by the researcher proved useful in the processes of determining and measuring achievements in teaching 21st century skills. During our professional development course, the focus was on collaboration and communication. In the interview, she expressed that learning is permanent and effective through collaboration. Therefore, she noted that the professional development course facilitated improving her teaching. She also emphasized that having a collaborative working culture helped her to create innovative projects. She found it effective to create lesson plans with the researcher and review it with other attendees of this research. She stated that implementing constructivist approach during the professional development course helped her to develop a profound understanding about collaborative methods.

On the other hand, she proposed sharing the outcomes of this project with her colleagues who were not able to attend the project. Merve hypothesized that sharing the results from this study might help her colleagues to develop their understanding of effective Science and Mathematics teaching. Merve, Zeynep and Naz continued to work collaboratively beyond this research; they also worked on a paper as Merve aimed to present initial outcomes of her classroom implementations in the Good Practices in Education Conference held by Ministry of Education.

In addition, Merve stated that this was their first professional development course organized in their school and she thought it was very convenient for them to attend. During the professional development meetings, Merve emphasized having a professional development opportunity which was school based, allowed group study, and embedded in teacher work developed her pedagogical content knowledge. Merve stated that after covering the lessons, self-evaluating her lessons, and writing reflective diaries about her teaching were effective ways of learning. She also emphasized that researchers' role in this research helped her to evaluate the effectiveness of her teaching.

4.1.1.2.9. Knowledge of 21st Century Skills

During the research, Merve continuously sought opportunities to develop her students' 21st century skills. As well as the standards for 21st century skills, she included the assessment of the standards of 21st century skills in her lesson plans. For example, Merve designed "problem solving skills in real life context activity" to evaluate her students' critical thinking and problem-solving strategies. Also, she designed a Collaborative Working Rubric to assess students' development in collaboration and communication fields. Merve created activities in which her students' solved problems in all of the integrated STEM modules.

Besides, Merve focused on life and career skills in her lessons. Merve stressed introducing STEM related careers while teaching each module except the first module. Merve had chosen the careers relevant to the theme of the module. The reason behind this was Merve thought that in low socio-economic communities, students were lacking in

guidance and counseling about life and career skills. Merve wanted her students to become conscious of several STEM related jobs and consider pursuing these careers in the future.

Moreover, Merve expressed in her reflective journal that group studies were beneficial for her students to develop their collaborative and communicative skills as well and to grasp the ideas of the lessons. There were only two modules in which she did not utilize the group study, and she explained that she had negative feedbacks on individualistic studies from students. She expressed that after these feedbacks, she designed the upcoming lessons as she utilized group studies as teaching strategy.

In summary, Merve focused on developing 21st century skills in all modules. Specifically, Merve focused on life and career skills, collaboration, problem solving, critical thinking, creativity, and innovation as well as communication.

4.1.2. CASE 2- NAZ

4.1.2.1. *Beliefs of Naz*

Naz generally studied with the traditional approach in STEM education, apart from her limited constructivist experiences during her education life. For this reason, she holds traditional beliefs about learning and teaching. However, Naz's educational beliefs are changing towards a constructivist approach. As Naz, like Merve, developed a constructivist approach, she attributed these new beliefs to integrated STEM education. Naz, unlike other researchers, stated that she believed in the importance of social-emotional learning support. In general, she has negative feelings towards Science and Mathematics disciplines. Her limited positive experiences were also in preparation for and during university education. She views STEM education as a learning model that engineering, and mathematics disciplines put at the center. Perceptions of technology and engineering disciplines began to form for the first time during her professional development, and she stated that there was a lack of content knowledge in these areas. Contextual beliefs show that Naz's working environment didn’t support her professional development. The reasons for this are the inadequacy of the physical environment in the school, the lack of family support, and the expectations from the teachers regarding the curriculum in the education system. In addition

to these, Naz believes that studies on integrated STEM education will contribute to her professional development and that students will have positive learning experiences with these methods. In the next section, Naz's educational beliefs about STEM education are examined in detail under sub-titles.

4.1.2.1.1. Beliefs about Nature of Learning and Teaching

Naz's beliefs about the nature of learning and teaching were examined through interviews, focus group interviews she attended during her professional development course, and data collected during her classroom practices. The analysis of the data shows that Naz's beliefs about the nature of learning and teaching changed and developed during this research. Naz's beliefs about learning and teaching STEM disciplines at the beginning of the research consisted of traditional beliefs. During the professional development course, it is seen that Naz's constructivist beliefs began to develop and come to the fore. In addition, unlike the other participants, Naz developed a belief in the current study that social-emotional learning had an influence on students' learning. Naz's contextual beliefs and inadequacy in her pedagogical content knowledge prevented her constructivist beliefs from being reflected in her development and teaching.

First, Naz's beliefs at the beginning of the research will be presented here. Later, Naz's developing beliefs during professional development course and finally her beliefs about integrated STEM education will be presented.

Naz's traditional beliefs about the nature of teaching and learning in STEM disciplines emerged in the first interviews. Naz emphasized the role of the teacher in transmitting knowledge so that her students could comprehend the subject. Moreover, she emphasized her belief that students must memorize and repeat the methods handed to them in order for them to learn.

Naz explained her understanding of teaching in general during the focus group meetings. She exemplified her way of teaching mathematics as:

> For example, let's say we write the problem, let's say everyone has finished writing the problem on the board, for example, I say that when they finish writing, you can move on to the solution part. At that time, I am waiting by myself, for example, I get

> up and walk around one by one. I look at everyone's operations one by one, I check them after that. But for example, I have solved a few of the same question.

Moreover, Naz showed the traditional understanding regarding mathematics lesson implementation. While she was arguing about the importance of waiting for students with a slower pace of learning, she revealed that her teaching routine included solving the same type of problems for many times, showing how to solve a problem to the students, then posing a problem and waiting for students to solve individually.

Naz's developing constructivist beliefs appeared in the data analysis of the interviews and transcripts of the professional development meetings. According to Naz, children are natural explorers. She added that children try to understand world around them.

> Naz: It is a very important thing for children to discover. It's actually something that starts from childhood, from infancy. From the moment the child starts to speak, in fact, we call it curiosity, discovery, that is, nature, don't look at it and try to understand what it is. (…)

She said that her belief came from her observation of children. She gave an example from her daughter:

> Naz: For example, my daughter does not speak now. She says "uh uh" here she is showing something maybe she wants to take it. A small ball, for example, has something in it and makes a noise. She takes it, plays it, and puts it in her mouth. Of course, I don't know exactly why she did this; then he pulls out something else and tries to hear such a sound. I don't know exactly what this is, but maybe a little exploring.

In addition to this, improvement in Naz's beliefs was observed during the professional development course from traditional to constructivist. When I asked all the participants, 'what are the main indicators of being successful in mathematics and science', she replied: "In my opinion, a student who spends a lot of time on these lessons is successful. Also being able to find her own solution." As it can be seen in her statement, she emphasized the importance of allocating time and having your own solution to the problems were two indicators of being successful in these disciplines.

Naz's beliefs, which changed and developed in her professional development course, later transformed into a form that would highlight the constructivist approach. As the constructivist learning-teaching approach developed, Naz, like Merve, kept her beliefs about learning and teaching in STEM education separate from learning in general. Moreover, Naz idealized the constructivist approach in her mind. The transformation in Naz's educational beliefs could not be fully reflected in her practices due to her contextual beliefs and deficiencies in her pedagogical content knowledge.

According to her, STEM education allows teachers to address students' multiple intelligences, and thus allows students to be active during the lessons. Collaborative learning is involved in STEM education, and teachers are expected to be passive. According to her, integrated STEM education covers several steps including planning, group studies, drawing, communicating, designing and evaluation. She said:

> (…) in the integrated STEM model, the student plans, draws, works in groups, communicates, designs, and finally presents his/her evaluation together… From the child's point of view, the lesson is full of benefits, and you emphasize his verbal intelligence, and his logical intelligence comes to the fore. There is teaching in many areas of intelligence.

In addition to Naz's constructivist beliefs in STEM education, unlike the other teachers in this research, Naz made an emphasis on the roles of social and emotional support in motivation. She said that when teachers welcomed students with a smile and answered their questions all the time without judgement, it could increase engagement. She also said positive teacher – learner interaction might have a positive effect on learning even in later years in education.

> So, it is very important for the teacher to never frown, to greet him with a smiling face every time I go and to answer that question in learning…. The comfort of knowing that you can ask whatever you want. Or, for example, … not saying how you don't know about it.

On the other hand, it is seen that Naz idealizes the STEM model and has misconceptions about the role of the teacher in the STEM model. We see that she passively perceives the role of the teacher, who should be in the "guide" position in the integrated STEM model.

When I asked during the interview what she thought about teachers' role in integrated STEM education, she noted that she believed teachers were passive and the roles of the teacher were to pose problems and talk about the process. She said she believed students were capable of learning by themselves. It can be concluded that her image of teaching in integrated STEM education is the reverse of her image of teaching in general. Naz made an emphasis on students' active role in integrated STEM education. According to her, without having a teacher, students can discover or solve problems. "The most important thing is that in STEM education, the teacher is not involved at all. So, the teacher just asks questions. Maybe he/she talks a little bit about the process, but so the kids can do it there alone without a teacher. In other words, we can say that a teacher is not active or passive. So, this is the most important difference from traditional education; teacher factor."

Her statements regarding the assessment in integrated STEM education reveal that she believes students may learn in group studies better. One of the aims of the professional development course was focusing on students' thinking by using several methods and assessments. Naz developed her constructivist beliefs as she participated in the task of lesson planning. She stated that students would improve their understandings during a group study even though it was not observed from outside that they participated actively.

However, as Naz's understanding of the principles of learning changed towards a constructivist approach, just like Merve. It is seen that she associates her beliefs about the constructivist approach with STEM education, while she associates her behavioral beliefs with learning in general. And since she cannot think of her pedagogical beliefs about STEM education separately from the context of the school she is currently working in, and she has deficiencies in pedagogical content knowledge, she positions it as a difficult method to apply in the school she works in.

The following data obtained from our interviews reveal that Naz defines STEM education in the context of the school she works in: "So, in my mind only the following occurs: Well, if we constantly try to apply it for each lesson, sometimes we may not be able to integrate some lessons into each other. (…) So, for example, is there an engineering design in every subject? Or is there a point in forcing him now? I think.".

This quotation comes from her orientation towards what needs to be taught. She believed that she needed to cover primarily the current standards with this new method of

teaching. Therefore, she questioned how she might fit this new education method into the current curriculum in which she was in charge of teaching in given time period. While there were no engineering standards in the current curriculum, she thought how she might be teaching both mathematics and science curriculum related to the engineering curriculum. As it can be seen, she believed it might be impossible to apply integrated STEM curriculum all the time. Her understanding of STEM education was limited to teaching current standards.

On the other hand, since her image of teaching in integrated STEM education differed from traditional education, she questioned how she could track and assess student learning in STEM education. It follows that she questioned what kind of assessment tools she might use instead of defining the objectives of teaching first and selecting appropriate assessment tool accordingly. Therefore, she thought it was not an easy task for her to assess student learning. Also, she expressed her low self-efficacy about her knowledge of assessment in integrated STEM education.

4.1.2.1.2. Beliefs About the Nature of STEM Disciplines

This section analyzes Naz's beliefs about the nature of STEM disciplines under four subsections. These are: (1) Naz's feelings, (2) her own experience, (3) her conceptualization of the state of each discipline in integrated STEM and (4) her beliefs about the nature of each discipline.

Naz had negative feelings towards mathematics and science in general. She said her negative feelings were based on her mathematics and science lessons in her elementary grades. Nevertheless, her feelings changed later. There were three reasons for it; first of all, her father was a mathematician, and her father's identity was interlinked with her mathematics identity. Second, mathematics teachers' social and emotional support had a positive effect on her changing identity. Third, in her college, science instruction made students involved in experiential learning. Therefore, she thought learning became tangible and easy.

On the other hand, her feelings and experiences in mathematics and science were intertwined. Consequently, as I present her feelings toward mathematics and science, her past experiences would also be seen. She expressed her feeling toward mathematics like this:

> We were taught that mathematics was difficult. It consisted only of numbers and problem titles. But these numbers and problems were results-oriented. If we got to a result, we were successful. The anxiety of not reaching the correct result in mathematics pushed me to failure in primary school. But it didn't stop me from loving math. I always felt that I would be successful in math class. Because this lesson was not as difficult as the teachers said. (…) My father's mathematics major never discouraged me from this course. (…) I realized that I had to ask everything I did not understand during the preparation period for university. I never gave up on my math teacher. I think I was on the right track. My teacher has never closed his doors to me. Thus, the path to success in mathematics was opened. I was very happy.

She expressed her feelings toward science as follows:

> Science teaching consisted of abstract concepts and therefore it was less memorable. (…) Science teaching was always something that was taught by reading from a book. For me, it was no different. I would never learn. (…) In science teaching, I only encountered teaching through experience and observation in the laboratory at university. For the first time, teaching science became concrete and easy for me. When I shared this lesson with my students through these methods, I felt that I was successful.

In summary, Naz's past experiences in mathematics and science disciplines caused her to develop a perception that these disciplines were difficult and abstract. While describing her past experiences, Naz usually talks about finding the right answer to the given question, reading book chapters to them, and making them memorize predetermined rules and symbols. However, her father's graduation from the Department of Mathematics and her efforts to develop a positive belief in herself and the constructivist approach of her teachers had positive effects on her feelings about these courses.

Naz stated that she was exposed to traditional learning in her K-12 years. She said there was no relation between these two disciplines. In addition, she said she didn’t have colleagues who interested in or could be competent in teaching mathematics and science during her professional life. Her only positive experience on collective efficacy was the professional development course they attended together.

Her impression of her mathematics and science education is as follows: “I didn't realize the relationship between math and science lessons in elementary school. To me, mathematics and science were two separate courses.”.

In her mathematics and science autobiography, she expressed her traditional learning experience and its effects on her. On the other hand, her own teaching experiences show that her colleagues had no interest in teaching mathematics and science: I did not have a circle of my peers who were interested in mathematics and science teaching. I have had group work (STEM activities) in my professional life, and it was very productive and impressive.

According to Naz, theme comes from science in integrated STEM education. In addition, engineering and mathematics are the central disciplines. Naz’s definition of STEM education focuses on problem solving and design.

The first interview with Naz revealed her understanding regarding STEM education: “So, I think STEM, well, is to develop a design based on problem solving and solve a problem with the design he/she makes.”.

She stated that engineering and mathematics had important roles in designing. When she said design, it meant drawing a prototype, using concrete materials to build a prototype, if something needed to be changed, then turning back to drawing and editing was needed. Therefore, her understanding of design process requires going back and forth between drawings of prototype and concrete material.

> Actually, STEM education is a very visual thing, so the word design always comes to my mind. In other words, when I say STEM, I always have a design and a math subject in mind. I have those two things in mind. Drawing a prototype and arranging it; always a drawing. For example, you are drawing the product you are going to make. You start the product. Then, when you notice something missing while making that product, you go back to the prototype and draw it. You continue after the drawing and then you go back and forth between the two. Namely, visuality, design and mathematics. So, these three things have always occurred in my mind (from initial interview).

She emphasized designing and creating prototype was an important component of the integrated curriculum. While testing the new product, using measurements and calculations are needed. In conclusion from her statement, it can be understood that engineering and mathematics are the central disciplines. In addition to her definition of integrated STEM education, she specified roles of each discipline as such:

> Well, the role of mathematics is always about measurement, … numbers and logical things are definitely involved. (…) in tower construction, we can always think of its height and base measurements (…) Its role in science, ii subject, that is, the theme is generally always related to science. Therefore, in the design of all courses, the learning outcomes should go one-on-one with science.

Naz's knowledge in engineering and technology disciplines developed informally after she started her professional life. Therefore, the information in these fields is based on the context in which it is included. Considering that she works in a low socio-economic environment, it is seen that she does not have deep-rooted beliefs about these disciplines and her interpretations are ambiguous. I asked her how she conceptualize each disciplines roles in integrated STEM education.

> Engineering design is used in the drawing part. (…) The technology part, I don't know much, but I guess it has to do with coding techniques or something. But I don't know that part of it yet, frankly I don't know much about it in the technological part. But we can do something like this in the technological part, for example, we can always show how to attract attention in presentations. In the attention-grabbing part, I think we can say that technology is used.

Thus, our interview with Naz revealed that critical areas that could be involved in integrated STEM education were operations and measurement. Science is the theme of the integration since Naz believed all the standards were in parallel with science. Also, she pointed out while they were doing drawings for prototype, they used engineering design process. Additionally, Naz believed that technology consists of coding and using technological devices to draw students' attention. She added that since she didn't have the content knowledge of technology, she made students watch videos especially at the

beginning of the lessons. The way she used technology in her STEM modules aligns with her beliefs.

When Naz's beliefs about the nature of each discipline are examined, it is seen that her beliefs about the discipline of mathematics changed towards the constructivist approach during this research. However, Naz maintained her previous beliefs while developing new beliefs about mathematics. Maintaining her previous beliefs is related to the context in which she is. Although her beliefs about the engineering and technology disciplines began to form during her professional development, her beliefs about these disciplines similarly are formed based on the context.

Although Naz's initial beliefs about mathematics were relational, she developed instrumental beliefs about this field during her research. However, she does not completely give up on her previous beliefs. When her beliefs in the developmental period are examined, it is seen that on one hand she thinks that mathematics is a discipline in real world context "Mathematics is already everywhere in every field." On the other hand, she teaches her own understanding of how she perceives mathematics and how she teaches it as:

> For example, we try to explain process-oriented mathematics and problem solving so that they can do the mathematics in the exam. Now, we see our own mistakes, that is, the mistakes made by our teachers (relational beliefs) and tell the children about that process, such as using that mathematical sentence in mathematics, for example, we explain the process, but we prepare the child for the exam again, that is, so that the child can do well in the exam again. But so that he can understand the logic. So here I am throwing a pool problem, solve this problem, not because this problem can be solved like this; but again, preparing the child for the exam by extending that process a little more, making it endearing or entertaining (…)

Thus, she had two different forms of mathematics in her mind: mathematics in real world and exam mathematics. She thought real world mathematics included problem solving, giving extra time, students' own thinking and fun. Exam mathematics involves solving the same type of problems in certain ways, especially how teachers solve. However, the fact that Naz's changing beliefs do not include conceptual learning reflects the deficiencies in her pedagogical content knowledge.

At the end of the research, Naz thinks that both mathematics and science are a reflection of the real world. Furthermore, she related mathematics to the process and mathematical logic, and science with concretization. In that perspective, one may say that she had constructive understanding towards these disciplines. When I asked them what three words came to their minds when they heard mathematics and science, she replied:

"Mathematics; Process Logic Science

Science; Concretization Science World"

On the other hand, Naz stated that engineering meant designing and drawing prototype during the professional development meetings. And the critical areas in mathematics were numbers and measurements. Naz stated that technology meant coding. However, since she lacked sources and content knowledge in this area, her use of technology was limited to playing videos through a projector.

4.1.2.1.3. Beliefs About Context

The environments in which teachers work can affect their professional motivation and therefore their approach to teaching (Livingston, 2014). The conditions that teachers are in can be effective in the creation and presentation of knowledge and their classroom practices. For this reason, the effect of teachers' knowledge on environmental conditions on the scale of country, community, school, student, and teacher will be examined under this title.

Naz sees three situations are related with country context in integrated STEM education. First, because of the current education system sufficient importance is not given to teachers' professional development in public schools. Second, lack of laboratories and materials limits teachers' ability to apply integrated STEM curriculum. Third, following current curriculum in certain periods of time limits her ability to use new methods in her class.

The episode below summarizes Naz's views about who values professional development for teachers in Turkey:

> We recently attended a professional development course at a private university. Iii, the people who came were generally people from private schools. For them, this course was a reference. Well, there were three of us from public school. … it was

> possible to teach in a public school without attending a professional development course (…) They attended this training because there is a salary gap between those who have received STEM education and those who have not. Of course, this is not the case for us public school teachers (initial interview)

As can be seen, these three public school teachers were the first and only teachers who attended a professional development course during the winter break. Even their instructor was surprised by their attendance. Naz also underlined the way her instructor was surprised: "Because there wasn't much going on in public school." According to Naz, most of the participants were science teachers. And most of them were private school teachers who were receiving their master's degree. Naz also emphasized that all the teachers except them had external motivation to attend this professional development course such as contracting with a better private school or promotion.

During a professional development meeting when Merve expressed her idea that the system encouraged teachers not to develop themselves, Naz agreed with her and added: "And this brings with it the following: the teacher does not try to improve himself/herself. Exactly why should I force myself?". She also related this idea to how a project named "Fatih Project" was conducted by government a few years ago in her school. The aim of Fatih Project was to supply tablets to public schools and train teachers in this field to integrate technology into the lessons. She recalls that when teachers wanted to use the tablets for the first time, the school manager said teachers shouldn't use tablets in case they should break them down. She criticized school managers' attitude.

On the other hand, while Naz was discussing using new methods in her classroom, she expressed her frustration of how teachers were required to teach only the standards in the given curriculum in given time period. She believed this situation restricted teachers' enthusiasm to teach with methods which required inquiry.

Naz believed family collaboration was missing in any other method other than lecture method of teaching. She had experiences with families as they questioned her method and content. Because of the lack of materials and authentic learning spaces in the school, she needed family support when she applied new methods in her classes. It can be seen in the excerpt from the professional development meetings:

> There are parents who say what the benefit is. … we ask the child for a lot of materials for STEM activity, and then they get out of order too (…) he tells me not to come up with a terrible idea. Sometimes, for example, a parent comes and says, I wonder what you did in the lesson. In this case, you have to show something from the curriculum in front of you (…) I have no doubt how the parent will react when the lesson is taught.

Additionally, Naz agreed with Merve's ideas on how families' help was missing on homework especially that required inquiry, questioning, and doing research:

> We try to do everything in the classroom. Because we can't send anything home. The thing that comes from home, the activities done at home are always done for the student, and this is something we already know. That's why we try to do everything in class (from professional development meetings).

Naz's beliefs about school context show that on one hand she valued developing current physical facilities and tackling with poverty, on the other hand she had a fixed mindset about poverty. Naz said that during the professional development course they kept thinking of how they might apply integrated STEM in their own school and in what ways they might use the knowledge in their schools:

> In that process, for example, we always thought: 'As you talked, we said; what can we do at school? How can we apply this in our own school?' For example, if there is a laboratory we can set up in the classroom in the future. In other words, as you talked, something always came to our minds about STEM education and how we can apply it to children. Things like 'How can we plan, how can we implement it, what kind of laboratory can it be?' have always come to life (during the professional development course).

During our interview, Naz said that they had attended STEM & Makers Fest / Expo in Hacettepe University. Her experiences give important hints about her beliefs regarding the lack of materials and classroom size:

> R: What did you intend to see at STEM & Makers Fest/ Expo?

> Naz: So actually, our purpose of going there is related to STEM, um, what has been done better? (…) three-dimensional printers, coding, Legos, designs… Our aim was to see what was done and to distinguish what we could do out of them. And what did we see? We saw that sometimes it could be a very costly thing. We also saw that sometimes it couldn't be achieved with just a few groups, that is, with a very large number of students.

One of the most important inferences that can be made from Naz's comment is how her beliefs about STEM education in the context of school hindered her development in pedagogical content knowledge. Naz's lack of control over changing the context at school also prevented her from developing her pedagogical content knowledge.

Naz thought that slow-learning students and students with a learning disability would benefit from integrated STEM education better than successful students. The comment below illustrates her understanding about students with different backgrounds and with different paces of learning.

In the interview after the professional development course, I asked Naz, "What kind of applications would you like to make in your classroom with STEM applications? what is your goal?" I asked:

> And my focus has been to show STEM to children with learning difficulties or slow learners. Actually, I always wanted to deal with this before. Because I can't get a child already successful excited about it. So, when I showed him those materials, when I told him about that process, it seemed like he wouldn't be excited, but the slow learner would be more excited than him.

She believed integrated STEM education would contribute to students' skills such as collaboration, decision-making, reasoning, communication. Also, she thought students would benefit from creating designs.

Naz stated that she depended on students' motivation during the professional development course. However, in spite of her beliefs in children's effort, she thought that some of the students wouldn't like to solve the given problem. In that case, she thought it might be better if teacher didn't give more time for these students, because these students

were lacking in motivation. She believed that teachers needed to consider marginal benefit over each student's learning.

On the other hand, she noted that her current students' social skills were underdeveloped. She thought her students were generally withdrawn and she wanted to engage them in content better. Also, she believed her students would become more sociable and express themselves better when an opportunity was given:

As a teacher, Naz believed that teachers would benefit from teaching integrated STEM curriculum in several ways. In addition to this, Naz believed that a professional development course would give rise to new ideas to be implemented in the classroom. She stated that the professional development course was very productive, and she is excited to implement methods she learned.

4.1.2.2. ***Pedagogical Content Knowledge of Naz***

As we examine Naz's pedagogical content knowledge, development and change during the research, it is seen that Naz planned to provide a student-centered STEM education in which the lessons were associated with each other. She aimed to design an active learning experience in which her students would take the responsibility of learning by using hands-on activity and material design in her lessons. In-class practices have shown that students participated in activities, designed materials, and experienced cooperative learning during education, but these practices do not include conceptual learning and in-depth teaching of learning outcomes. Although she wanted to use the prominent teaching models in STEM education, such as the engineering design process and modeling, their applications were evaluated in the category of "misapplication lesson" because they were insufficiently related to the outcomes during these applications. Generally, after these activities, Naz taught using traditional methods. Naz excluded the outcomes of the technology discipline and teaching strategies from her practices. Naz, who was seen to have a good command of the curriculum outcomes and current curriculum knowledge, also included the learning outcomes related to the engineering discipline in her lesson plans, unlike the other participants. It is determined that the mathematics and science achievements that Naz included generally appealed to the students' lower cognitive levels. Although Naz emphasizes high learning goals for her students, she has developed practices that are far from learning goals that will challenge her students cognitively. In the lessons that she developed with context integration by putting

science and mathematics at the center, she made designs by taking into account the interests and socio-cultural characteristics of her students and aimed to measure the learning of her students closely. However, her lessons consisted of mostly hands-on activities due to the inability to set clear learning objectives and assessment criteria for her students. During the research, it was seen that context knowledge affected the development of other PCK components. She aimed to develop collaboration and life and career skills among her students, one of the 21st century skills. During the research, it was observed that her knowledge in the fields of Knowledge of teaching strategies, Knowledge of student, Knowledge of assessment, Self-assessment improved. However, it is observed that low self-efficacy and low CK caused a limited PCK development.

4.1.2.2.1. Knowledge of Teaching Strategies

When it comes to the knowledge of teaching strategies of the participant teachers, it was presented under two subtitles. These are subject specific and topic specific teaching strategies.

Teacher knowledge about *teaching strategies* was investigated in this section. The analysis of the data on Naz's knowledge of teaching strategies has shown that Naz included teaching strategies, mostly in science and engineering, and partially in mathematics, into her classroom practices. Naz aimed for her students to be active in her lessons and achieved this by making use of hands-on activities. However, she made use of teacher-centered methods in teaching the learning outcomes and ensured that the teaching was mostly done by her or by using the whole class question-answer methods. It is seen that Naz, like Merve, carried the strategies applied in the professional development course to her class. In addition, Naz wanted to benefit from the engineering design process and mathematical modeling, but since she could not adequately associate the activities in these applications with the learning outcomes of the lessons, these lessons were evaluated in the misapplication lesson category.

In her first module, Naz designed a group study for students to model a garden as they looked through the eyes of a landscape architecture. After students designed a garden by using concrete materials and a ruler, Naz had them model their designs in the backyard of

the school. By looking at their designs on the sketch, students modelled their designs in the backyard. Then Naz asked students how they might calculate the length of the garden. By having the whole classroom discussion, Naz made her students question differences between using different types of tools to measure the length.

Naz initially decided to use mathematical modelling for this module. However, instead of posing one mathematical model question, she posed a series of questions one by one to make students reach the final design. In the following paragraph, I will explain in which sequences Naz posed questions to have her students model a design of a garden in detail.

Naz's first lesson started with grouping the students. Then, Naz gave each group materials such as an easel pad, a ruler, and pencils. Naz showed a video of the backyard on the SMART board. Then as a whole group discussion, Naz asked students in what ways they might design this garden and which plants they might use. With question- answer method, Naz asked the whole classroom "School principal wants you to redesign this garden. Why would he be thinking in this way?" Afterwards, the students answered this question as: "Because it is not clean, because there is no flower in the garden, because plants were dehydrated". Then Naz asked: "If you should design this garden, what would you do beforehand?". A student answered: "We must imagine and draw." Then Naz gave them a list that had information about the plants and told the students to work in group so as to draw their garden sketches. Naz told them to use the ruler to calculate the lengths between plants. However, she gave the students 5 minutes to draw their sketches. Therefore, she asked students not to use the ruler. The students were not able to complete their designs within the short time frame completely. She made the students view the other groups' sketches after 5 minutes. Then she took students to the backyard of the school. Naz asked them to model their designs in the garden by using meter sticks, straws and post-it notes. The students used meter sticks to calculate the lengths between the plants. Afterwards, she did an assessment with open ended questions related to converting measurement units for word problems.

She revised her lesson plan according to our meeting since the tasks she created didn't allow high cognitive demand for modeling. According to the (Miller et al., 2011), modeling process involves posing a problem, formulating a model, analyzing, and performing

operations, interpreting results, validating the conclusion, and reporting the conclusion with explanations.

In the second day, she started the lesson with a presentation in which she showed examples of gardens designed by landscape architectures. She also presented examples of the sketches. This time she limited the sketches to 10 plants. She also assigned one geometric shape to each group; therefore, each group would have different garden designs. She also gave a list of the required lengths between several plants. For example, if students chose to plant cacti, they had to draw these at intervals of 50 cm. Naz, then, took students to the garden once more and asked them to model their designs in the garden. She assessed students' mathematical knowledge with open ended questions. Naz observed her students struggling to adapt their sketches to the garden. She also noted that the lengths she defined on the list were not appropriate to implement for students. "They had a hard time applying the shape they designed during the drawing in the garden. They needed simpler shapes. The length measure chosen while measuring in the garden was too much. (For example, 1 m distance was too much for the lily. Therefore, they could not create the design form)". She, then, updated her lesson plan once more according to her observations.

In the third day, she told each group to choose two plants and had the same process with students. Then, she assessed students' mathematical knowledge with converting measurement word problems and explanations of them. After the implementation of the first module, she realized that she needed to adjust the design's configuration for the mathematical model activity. During our meeting after the lesson. I asked about how she would plan her lesson if she had a second chance, she expressed her ideas as:

> I would inform students about garden design architecture by using visuals. I would set criteria during the design process. For example, let each group have a different garden design style. It can be said that they can benefit from geometric shapes. For example, a group may place their plants in a circle. The other group can place their plants in the form of a square, etc.

She could not effectively implement the lesson she had planned. The analysis of data from classroom observations, lesson plans, Naz's reflective journal and our one-on-one meeting indicated that she had limited knowledge of mathematical modeling.

Naz started the second module with the question-answer method. She pointed out the need for recycling for the environment and gave examples of recyclable waste. Afterwards, she grouped students and gave them a worksheet to work together on the answers to the questions. Then, Naz explained the activity she had planned for this module. First, she introduced a new STEM career "industrial engineer" related to the current topic; then, she told students to imagine themselves as industrial engineers and design a recycle box. She added that there was a competition in the school and which classroom collected more recyclable waste would win. Students designed a box for a selected recyclable waste and presented their boxes to the whole classroom. Even if Naz referred to the method she used in this lesson as Engineering design process, the elements of an engineering design cycle were missing, and besides the lesson did not have a science connection. Therefore, this lesson can be categorized as a misapplication lesson since it is a hands-on activity lacking in the connections with science standards.

The other subject-specific strategies that Naz used were classifying concepts with post-its, storytelling and station rotation model. Naz used classifying concepts with post-its methods to make her students group the objects according to their energy sources. Naz gave students a list of objects such as iron, lamp, handheld mixers, candle, hair dryer, a clock. Then she told her students to group these objects according to their energy sources. Naz reflected this activity on her reflective journal as: "I had to do guide students on how to group the objects and label the energy sources. I believe since it was their first time, they struggled. I must use this method more often in the future." Naz started the last module by telling a story to attract students' interest to the topic of science. Naz's story was about how to avoid electrical hazards by using electricity safely. Then, Naz made students work in groups in station rotation activity. She set up 4 stations which are (1) case study station, (2) slogan station, (3) make a list station and (4) visual arts station. Students rotated in given time and completed the tasks.

In summary, Naz used hands-on activities mostly and after each activity, Naz summarized what students thought about the activity with the whole group discussion. The main characteristic of Naz's teaching was mostly teacher centered. However, Naz allowed her students to be active during the hands-on activities.

When the analysis of the data is examined, it is seen that Naz used *topic-specific* strategies on fractions only in Module 4 among the lesson plans she created. In this module, Naz wanted her students to share 4 wafers equally between 6 students. After the students solved the problem with their own groups, Naz asked the groups to share their strategies. It is observed that students mostly solved the problem by using fraction strips. Naz showed her students how to solve the same question in different ways by using length models as a new method. On the other hand, Naz stated that she would use portioning with length models as an alternative method in her lesson plan, but it is seen that she could not use this method because she did not have enough time during classroom practices. Analysis of the data has shown that Naz's knowledge of topic-specific strategy was limited.

4.1.2.2.2. Knowledge of Curriculum

Naz's knowledge of curriculum related to the topics she included in her STEM lesson plans was investigated. Naz's knowledge of curriculum about topics she included was evaluated with the help of professional development meetings, lesson plans, classroom observations, interviews, and her reflections.

Interviews show that Naz mastered the changes and achievements in the curriculum. Naz benefited from the resources provided by the researcher, since there were no guiding resources specified in the curriculum required by the Ministry of Education in the field of technology and engineering at her teaching level. The standards in the field of engineering that Naz included in her classes were suitable for the level of the students. The standards in mathematics and science disciplines generally addressed the lower cognitive levels of students. Naz excluded the learning outcomes in the field of technology from most of the lesson plans (except one lesson). It is seen that there is a context effect at the country level while preparing the lesson plans, and with this effect, she tried to choose the outcomes in parallel with the curriculum and this in turn limited the course designs.

Naz noted that she made use of several sources to define the standards in the lesson plans. While she utilized the current curriculum to define science and mathematics standards, she used several sources for defining engineering and technology disciplines. She stated that, since there were not defined standards for the technology and engineering disciplines for 3rd grade, she utilized the sources from private universities' publications and books that were

supplied by the researcher. Since teachers in this research have concerns about time to cover the mandated curriculum in given time, Naz compared and contrasted between this high quality and up- to-date sources with the current curriculum.

In the second module, the task was to design a recycle box; however, Naz did not set the expectations for this activity nor included mathematics or science connections. Therefore, so-called engineering design project became an isolated, unrelated activity that depicted engineering as tinkering or craft project. Naz added mathematics and science standards to her lesson plans. However, during the implementation of the lesson plan, no connection to these standards is observed. Only if there are explicit connections to science and/or mathematics content will the understanding of content knowledge increase (National Research Council, 2009).

On the other hand, even though Naz added standards from technology and engineering, she mainly focused on learning objectives from science and mathematics during her implementation. In addition, a pattern came forward as I analyzed the objectives she focused on in her lessons. Most of the objectives in mathematics and science disciplines require only factual knowledge. However, conceptual, procedural, and metacognitive knowledge were set aside. This resulted in the fact that the activities require students to operate fewer complex levels of thinking (Ferguson, 2002). Considering lesson plans are guide for teachers' implementation, and chosen objectives define the level of the cognitive process, Bloom's taxonomy provides the systematic classifications of the process of thinking and learning. And according to Bloom's taxonomy, most of the objectives reciprocated to lower level of cognitive work.

Another important finding about Naz's curriculum knowledge is that she did not include the standards of the technology discipline while designing her lesson plans, similar to Merve's. The reason for this is that she thought that she did not have the opportunity to apply them in the school and classroom where she worked even when she included these disciplines. Another reason is that her content knowledge in the field of technology was not sufficient. More specifically, Naz, just like Merve, stated that she had not taken part in the curriculum related to this field while she was receiving her university education, and that she did not attend any training in this field during her professional life.

Interviews showed that Naz choses science and mathematics standards to be parallel to the curriculum. She stated that in some cases it prevented the lesson plans from being more effective and restricted the lesson plans she was making. Here, the effects of the curriculum implementation in Turkey can be seen. In Turkey, teachers have the obligation to complete the determined subjects within the specified time, and Naz tried to fulfill her responsibility to teach these achievements within the specified time.

4.1.2.2.3. Knowledge of Student

When Naz's knowledge of student is examined, it is seen that Naz had high expectations for her students and believed that her students would be successful. Naz knew the cognitive levels of her students, the characteristics of the socio-cultural environment they lived in, and their previous knowledge very well, and she considered the students' knowledge while planning her lessons. Also, in this research process, Naz developed a perception that there were methods that would enable her students, who did not actively participate in their previous courses, to actively participate.

According to data from our initial interviews, Naz was holding high expectations for all students who had an important role for equitable practices in classroom. However, it is observed that Naz did not reflect this belief to her practices. For example, for the first module Naz planned for her students to design a garden. During our interviews and lesson planning meetings, Naz noted that she would define criteria about how to accommodate the plants; accordingly, she planned to assess students' mathematical thinking. In contrast, during the implementation of the first module, she told students to design a garden by using the information she gave them as a list and their rulers. However, she did not set the expectations and criteria for the assessment of the activity. Therefore, students drew their sketches without using mathematical knowledge. Furthermore, Naz gave students only 5 minutes to complete their drawings, which is a very short period of time for the students who were at the 3rd grade. In addition to this, she stated in her reflective journal that students had a hard time understanding the meaning of the word "design" in the first module, which led them to be confused and frustrated.

On the other hand, Naz managed to attract students' interest successfully in all of the modules by using the context in which they were living. In the first module, she brought up

the school garden with which students were familiar. In the second module, she built on the students' knowledge about geometry and recycling. She also utilized a former activity that the school had put into action, named "recycling competition". In the third model, she used the school's front yard as a place for students to design an artificial environment. In the fourth module, she used chocolate bars as length measures, and in the fifth module, she utilized the standard which links learning with students' everyday lives. "Explain the importance of electricity in daily life by giving examples from the close environment of using electrical equipment." In the sixth module, Naz made students weigh their schoolbags.

Additionally, Naz built her lesson plans on her students' prerequisite knowledge in each module. However, it is not observed that Naz addressed her students' learning difficulties or developmental level or need. This is because in all of the lessons, Naz had her students do an isolated hands-on activity for which she did not set up criteria or effective assessment tools, which resulted in not addressing the standards in her classroom practices. She stated that her students were able to achieve the activities easily.

Naz noted during our interview that she did not utilize the integrated STEM methods in this research to teach a new unit or standard. That being said, Naz planned and implemented lesson plans within this research to review an already taught unit or repeat an activity in an already taught unit.

As analysis has indicated, there are two reasons behind this feeling of Naz's. First of all, analysis of data has revealed that Naz held low content knowledge. During our initial interview, Naz emphasized her concerns about her weak subject-matter knowledge in mathematics and science. On the other hand, in the lesson planning meetings well-designed tasks were shared with teachers to reduce their workload and help them to plan effectively (e.g., Corlu & Çallı, 2017; Erbas et al., 2014; Walle et al., 2013). However, Naz stated that contents from these sources were difficult for her. Secondly, Naz expressed her low- self efficacy about teaching integrated STEM education. Data from interviews have revealed that she considered herself as a teacher with low self-efficacy in teaching integrated STEM curriculum. This excerpt from our interview explains her low self-efficacy:

R: How do you conceptualize integrated STEM education?

> Naz: (…) So, if we say STEM is an education method, then it seems to me that we can apply it to every lesson. But we can't implement it, so it's as if it's on my mind too, that's what I think. But for this reason, I need to learn STEM completely. I need to learn more things; I think I'm missing out a lot.

According to Naz some students, who did not attend the classes during their traditional mathematics and science lessons, actively participated during STEM applications. She stated that with these practices, her perception of students changed. Naz expressed this change by saying "Students that I never expected used reasoning in the activities and solved the problems.".

4.1.2.2.4. Knowledge of Assessment

Analysis of interviews has revealed that Naz's initial knowledge of assessment in integrated STEM education was limited. Naz developed her knowledge during the research about the purpose of assessment and evaluation, how it would be done as well as about different methods. It is seen that she partially reflected this knowledge on its applications. For example, Naz developed and implemented formative assessment tools such as open-ended questions, gallery walking, presentation, etc. However, Naz's practices were found to be incomplete. When Naz's assessment knowledge is examined, it is also seen that Naz could not reveal the learning goals for her students well enough in the activities she prepared or in the assessment and evaluation processes.

During our first interview, when I asked Naz how she would measure students' learning, Naz's answers were found to be limited in her knowledge of the aims, methods and methods of assessment.

> Naz: I think it can be difficult to evaluate.
>
> R: In evaluating what, for example, how, what can happen?
>
> Naz: I mean if the children's presentations are an evaluation, I will do it. Well, can we say their attitude scale as another evaluation criterion? You know, their attitude towards this thing, well, towards this education. Well, that's measurable, and valid. It is valid, reliable. So that comes to mind. You know, the interest and attitude of

these children towards it… And the state of the product that comes out with the presentation they make.

Naz: Well, if the student makes the presentation, I can measure it like this. I have questions, I go based on these questions, so the student makes his presentation, or I ask. So, what kind of product did you come up with, what did you think about while making this product, what ideas did you have in mind? Did you all come to this idea jointly? Then it becomes a benchmark by which I will ask various questions about their attitudes later on. It's about how they feel. (…) At the end of the process, what was it like, how did you feel, what were the difficulties in doing this, what were the easy aspects for you, and what did you encounter?

As it been reported in the literature part there must be precise link between assessment and instruction to achieve the goal of the curriculum. However, as can be seen in the excerpt from interview, Naz's definition of the expectation from integrated STEM education and indicating how to assess these expectations were not clear.

However, during the research, Naz developed her understanding and aimed to use different methods in order to better follow the learning of her students. Naz used open-ended questions to better assess her students' learning. But, on the other hand, as indicated earlier, Naz hadn't defined clear learning goals for the activity she chose. Additionally, Naz did not include most of the learning goals in the assessment procedure. For example, Naz assessed students learning with open ended questions. She prepared a quiz consisting of 2 questions.

1-Why did you use meter and centimeter in your design?

2- How did it help you to use these measurement units while you were designing your garden?

As can be seen from this quiz, Naz aimed to better reach her students' learning with open-ended questions (compared to multiple-choice tests). But Naz only involved mathematics topics in assessment. Even though she built a lesson plan on engineering design process, mathematics, engineering, and technology content, she did not assess them. In order to be able to facilitate an effective evaluation, teachers must understand the principles of

how students learn, and they must understand deeply the content areas they teach (Brookhart, 2011).

At the end of a module, Naz wanted to implement gallery walk, a technique in which each group of the students visit the other groups' studies and give them feedback. Naz's use of this method seems to be an effort to increase students' metacognitive awareness. Naz's informing her students about the evaluation at the end of this application and giving them feedback was an important step to ensure meaningful learning of this activity, but Naz did not implement this step. Instead, only the students studied the work of their friends. These analyses alluded to the lack of knowledge of assessment because a good assessment provides opportunities for students to learn and self-regulate (Moss et al., 2006)

She reflected on her lesson plan during our interview when I asked: "What would you do differently?" as: "I would define criteria for the designing process." This comment indicates that Naz came to understand the role of well-prepared tasks in the students' learning. However, when I asked in what ways she would define criteria, her answer did not necessarily indicate engaging students by utilizing rich and challenging tasks (Sullivan et al., 2013). She answered: "For example, each group has designs different from each other's, or I might say students may use geometric shapes. Or while a group draws their plants on a circle, the other group draws their plants on a square." Teachers should be able to articulate objectives that are congruent with depth of thinking. In this way, curriculum becomes attainable and assessable. The reason why Naz could not engage students with rich tasks might be the lack of her content knowledge (Brookhart, 2011).

In the second module, Naz made students design recycling boxes. Naz evaluated students' learning with 3 open-ended questions. Students were expected to answer the questions in a written statement as a group. These questions were:

1. How did you go about designing the recycling box?

2. What waste material will be in this box? Why did you choose this item?

3. How do you think this waste material will become a new substance, can you briefly explain?

During the group studies, she supplied the needed materials such as a ruler, a meter, shoe boxes, stick, tape, a newspaper. And she added mathematics standards that required students to measure a certain length by using ruler or students used suitable units in all calculations and measurements. However, during the assessment, she only evaluated the whole unit with the questions above as in the first module. Therefore, the evaluation of the learning of most of the standards was not involved. Also, during the initial interviews she noted that she valued group studies. In parallel with this belief, she made students study in a group; however, she did not include the assessment of group studies. That being said, Naz's assessment does not reflect valued student learning targets.

4.1.2.2.5. Knowledge of Context

As a part of this research, Naz planned her lessons to implement them in her own classroom. In general, Naz's knowledge of context within the scope of this research appears in two ways. Her knowledge of the country and school context played a restricting role in planning effective STEM. Naz has designed and implemented integrated STEM education with limited materials, not including the family in teaching, integrating the technology discipline in a limited way, and determining the outcomes in line with the compulsory curriculum. On the other hand, she used her knowledge of the students' context to design her lessons in a way that would be closely related to the students' lives.

Naz used her knowledge of context with regard to school and country conditions to create lesson plans. Naz considered that her school lacked laboratories and classes were deprived of materials. Therefore, she limited her use of manipulatives, and she used recyclable materials; she utilized also technology only for watching videos and images.

Naz knew that her students would not be able to access to educational support at home from her past experiences with students and parents. Therefore, she planned all of her lessons to be implemented only in classroom. She didn't include homework in her lesson plans.

During the planning process, Naz used her knowledge of context to make her lessons relevant to her students' lives. She also focused on group studies as she thought students would learn in groups more effectively. Accordingly, in the first module, Naz planned to have the hands-on activity in the school's backyard as students were familiar with the space.

When students saw the videoclip of the backyard of the school, they immediately recognized where this video was shot. Naz attracted students' interest easily. In the second module, Naz started her lesson with a scenario which students were familiar with.

On the other hand, Naz used her knowledge of context with regard to the conditions of the country. She integrated her lesson plans with the current curriculum. She followed the mandatory curriculum to decide on which standards to use in her lesson plans.

4.1.2.2.6. Knowledge of Integrative Thinking

The analysis of lesson plans and reflective journals reveal that Naz's integrated STEM modules were designed as context integration. She centered science in the 2nd, 3rd, and 5th modules and mathematics in the 4th module, and both mathematics and science in the 1st and 6th module and she used the context from technology and engineering disciplines. For example, in the first module, Naz made students design a garden by using the information about plants and their knowledge about assessment. In the second module, Naz used scientific knowledge as a context. Naz divided students into groups and asked students to imagine themselves to be industrial engineers and made them design a recycle bin. While students used their mathematical knowledge such as measuring the length of the perimeter, or using suitable measurement units, students did not require the explicit use of science or engineering content to complete the activity.

In the third module, students designed an artificial environment with the given materials. And Naz expected them to answer questions in the context of science education such as "What are the differences between an artificial and natural environment?" or "How did you contribute to the environment in this garden you designed?" Therefore, students focused on the science content and used limited mathematical knowledge such as calculating the lengths of the materials.

To sum up, Naz used context integration, and while focusing the objectives from central discipline, students were not required to use engineering and technology content.

4.1.2.2.7. Knowledge of Technology Integration

According to data analysis of Naz's lesson plans and observation of lessons, Naz used technology in her integrated STEM lesson in three ways as Merve did. First, she employed Word, Web browsers, etc. while developing her lesson plans. Secondly, she used technology to communicate and collaborate with her colleagues, a practice created and supported by researcher as a part of this research, and thirdly, she used technology for her students to build knowledge by viewing images, seeing a video in two of the modules. It is observed that Naz used technology to create her lesson plans. She used online sources. Additionally, she used Word to create her lesson plans.

On the other hand, as a part of our study, I asked teachers to use Dropbox and google drive to collaborate with each other. Since this study took 6 months and included a professional development course, video recordings and audio recordings, we used technology to collect, keep and evaluate the data. Therefore, I wanted to keep all of the documents and resources available to the teachers. Teachers uploaded all the documents related to their lessons such as lesson plans, reflective journals, audio, and video records of their lessons. Therefore, Naz used technology to collaborate with her colleagues.

Additionally, her context knowledge about school plays a role in shaping her knowledge of integration of technology. In the initial interview, she stated that she might implement integrated STEM education only if there were not requirements for a good technological infrastructure. She stated that:

> Naz: Maybe if I had been told that we must have a technological structure like this, I would have given up on STEM, taking that education or being interested in STEM. But it caught my attention once, because it has an alternative and is feasible from kindergarten onwards.

Therefore, as can be seen, Naz's context knowledge about school shapes her knowledge of integration of technology. During the research, Naz used technology to show videos or images.

In her first lesson plan, Naz supported her teaching with the technology in a way her students would watch a videoclip of the school's backyard. Her choice of using technology

was to show the video clip as a context for the mathematical problem. The videoclip served the purpose of discussing real life situations related to the current topic in the classroom. Therefore, she used technology for her students to develop their hands-on activity and the students participated in the hands-on activity at the section she shared in the video. Naz used technology in another lesson to show her students images of the gardens designed by landscape architecture. However, Naz did not use these images to make discussions with students. Therefore, a teacher-centered approach was used while utilizing technology.

Furthermore, in another module, Naz showed her students a videoclip to explain how wastes around us affected the nature and to show the role of industrial engineer and the function of factories in the process of how wastes become renewable. Then she presented the idea of the activity she designed, which was to make a recycle bin. Therefore, she did not make a connection between the video and the activity; however, she used technology to give the context to the students.

It is not observed that Naz addressed to this objective during the implementation of lessons even though she added the technology objective to the fourth module's lesson plan "Students understand possible changes that technological progress can cause.".

4.1.2.2.8. Professional Growth

The analysis of the data has shown that Naz's professional development within the scope of this research was limited. When the reasons for this are examined, it is seen that Naz's low self-efficacy belief in applying STEM education and insufficient content knowledge are obstacles to the development of Naz's professional growth. Naz's areas of development in pedagogical content knowledge within the scope of the research are knowledge of teaching strategies, knowledge of student, knowledge of assessment and self-assessment. Naz also stated that the convenience of the current professional development course had contributed to her.

Naz noted that having professional development course in her setting helped her to attend a semester-long course. Moreover, current professional development course helped Naz to analyze her own implementation and understand in what aspects she needs to develop further. Conversely, this professional development course seems to have contributed to Naz

in a limited way in developing her PCK throughout the research. The underlying reasons were determined as Naz's low self-efficacy and lack of CK.

To start with, I will explain the analysis of the data which explains her low self-efficacy. Naz related her low self-efficacy to her lack of opportunity to implement STEM education. During our interview, she said that since she had never implemented integrated STEM education in her class, she was worried about her students' reactions. Naz: "Or for the kid, that's to say, what else should we say? Will the children perceive this as entertainment, not as a teaching method, but as having fun? I will see that in time. I know I can't answer you but because I didn't do it. (…)". Moreover, Naz expressed her fears for attracting students' interest to the related topic. She stated that her fears resulted from her past experiences.

"We have fears as well. You're going to start a new topic, how should I attract my students' interest, you see? Let me get attention, let me do something like that, that anxiety is still something from childhood. What should we do? Those concerns are still here with us."

Additionally, Naz stated that her knowledge about integrated STEM education was limited. "Well, as we generally don't know much about STEM (...)"

In addition, Naz stated that she had low self-efficacy beliefs about the nature of teaching process and roles of instructions. Naz remarked that she hadn't planned her lessons before she implemented them. Instead, Naz planned separate activities and put these activities into the lesson plan after she completed them. This indicated Naz's low knowledge of teaching. Also, she said that she was concerned if students couldn't achieve the objectives of the implementation. During our one-on-one meeting after she implemented first module, I asked her how she has planned STEM modules. She said:

> Let me say that I have such a deficiency. I actually taught the lesson first. I said I'd make the plan later. (…) There is a situation like this, Naz, I haven't done this yet. I did not do the course with STEM content as the first lesson of any course. In other words, the children did not learn something with this content for the first time, they consolidated something they knew or something I just told a little bit with this content. (…) So, I didn't teach this lesson without knowing anything from scratch

> during these five lesson plans. Actually, I should do it. However, I still have concerns about it. I think that if I work with this content, they will not learn at first. So, I hope I explained what I wanted to say. It's not the first time I've done anything they're going to learn with this content.

She explained the reason of her concern as: Naz's two important beliefs emerged as she explained why she could not implement STEM activities in her lessons to teach new standards: focusing on the results in education instead of process and beliefs about students. As can be seen, Naz focused on her students to achieve task; this belief of hers prevented her from implementing constructivist perspectives. Second, she stated her lack of belief in her students. She applied these beliefs in her interaction with students and the classroom practices. To sum up, Naz expressed her low self-efficacy in implementing integrated STEM education. This may have prevented Naz from developing throughout the research.

Secondly, I will explain the impact of low CK on her implementations. In this professional development course, our aim was to understand teachers' current states and develop their PCK and beliefs instead of equipping them with the content knowledge in STEM fields. Consequently, we highlighted all of the components of STEM PCK in general and offered teachers updated sources in the field. Along with this, during the professional development course, we implemented student-centered teaching methods as a way for teachers to discover how to use them. We analyzed the best practices in STEM education and discussed the possible ways to use them in their teaching settings. On the other hand, by focusing on teachers' own learning process, we aimed them to discover their own beliefs and perceptions toward STEM education.

During the professional development meetings, Naz expressed her lack of content knowledge on mathematics and science by associating it with her previous education process. During her K-12 education, she was exposed to traditional teaching in mathematics and science classes; she could not develop her knowledge sufficiently, she had a little opportunity to improve her mathematics knowledge thanks to the teacher who helped her during the university preparatory exams, and she was involved in the structured teaching knowledge during her university education for the construction of science teaching. She stated that she found the opportunity. In addition, when her data in the lesson planning

process were analyzed, Naz stated that STEM activities and content in the current sources provided by the researcher, as well as mathematical modeling problems, were difficult for her, so she did not use these sources. In addition, during the professional development course, it was observed that she generally wanted to include the subjects and achievements in mathematics and science that her students already knew in the lesson plan development activity in partnership with the researcher and other participants. It is observed that the standards used in lesson plans didn't address students' higher order thinking skills. As it can be understood, Naz's lack of content knowledge also negatively affected the development of Naz's PCK, and this hindered her development in the professional development program process.

Results revealed that Naz's CK negatively affected her PCK, and it is seen that Naz's knowledge of defining clear objectives was limited, as previously described in the knowledge of curriculum section. Additionally, Naz's knowledge of assessment was limited. According to the analysis of data, Naz focused on completing lessons in time and getting correct answers from students. On the other hand, by using critical reflection, Naz analyzed her initial lessons, and stated that she needed to plan her lessons, accordingly. However, she did not use these reflections to prepare her upcoming lesson plans. This may be another reason that prevented Naz from developing her PCK throughout the research.

4.1.2.2.9. Knowledge of 21st Century Skills

The focus of Naz's 21st century skills teaching was on collaboration. Naz employed group studies as strategies in all of the modules. As she noted during the interviews, she believed group studies helped students to learn effectively. Therefore, her implementations were aligned with her beliefs. Additionally, she stated in reflective journal that her students developed their communication skills as she allowed students to work in groups constantly.

On the other hand, Naz focused on life and career skills in her lessons. While teaching the first and second module, Naz introduced STEM-related careers. Naz chose these careers relevant to the main objective of the module. STEM-related jobs that Naz introduced to students were landscape architecture and industrial engineering. Naz used traditional methods to introduce these careers. For example, in the first module, Naz showed images of garden designs and she pointed out that landscape architects designed these gardens. And

without giving more information about the background of a landscape architect, she expected her students to design a garden as they think themselves as landscape architect.

To sum up, Naz had limited knowledge of 21st century skills to teach integrated STEM modules to facilitate students' knowledge.

4.1.3. CASE 3- ZEYNEP

4.1.3.1. *Zeynep's Pedagogical Beliefs About STEM Education*

Data analysis demonstrated that Zeynep was involved in a traditional teaching throughout her educational life. However, unlike Merve (who spent her educational life in traditional teaching), Zeynep developed a positive identity of the disciplines of mathematics and science as she benefited from this system, and therefore she believed that her students would also benefit from these methods. Unlike other participants, Zeynep had instrumental beliefs about mathematics and science. Zeynep's beliefs about the nature of learning and teaching show that the positive attitude developed by her students was a priority in Zeynep's teaching. During this research, Zeynep developed especially on how to reorganize the lessons that she taught with the traditional method in her classroom in accordance with the constructivist approach. Zeynep believed that professional development was necessary, and she worked in line with this belief in her professional life. On the other hand, Zeynep believed that some innovative methods in the integrated STEM model would be difficult to apply in the context they were in. Zeynep's traditional beliefs had been influenced by the examination system in the Turkish education system, and her willingness to maintain some of her traditional beliefs stems from believing that it would be to the benefit of her students. Zeynep defined the role of the teacher in STEM education as a guide and believed that applying this innovative approach would contribute to her professional knowledge. Zeynep saw the integrated STEM model as a model to teach these disciplines in accordance with the principles of the constructivist approach and in such a way that students could develop positive attitudes. However, Zeynep, like other teachers, marginalized STEM education and determined this new model as a teaching area without worrying about grades, rather than a method in which learning outcomes would be taught more efficiently. In addition, Zeynep

believed that STEM education was based on science and engineering disciplines and emphasized the organic relationship between engineering and mathematics. Besides, Zeynep emphasized the incomplete content knowledge of the technology discipline and, like other participating teachers, her belief that the situation of the school she worked in would not allow it to be an obstacle to the development of the content knowledge of the technology discipline. Zeynep stated that in the Turkish education system, teachers' lack of knowledge and experience in the system caused them to feel worthless. In addition, Zeynep, unlike other participants, valued contextual learning and the socio-cultural backgrounds of her students. She reflected this belief in her practices by associating the learning outcomes with the lives of her students in the process of processing STEM modules in her classroom. At the end of their practice, she thought that her students' learning with the STEM model enabled them to develop positive attitudes towards science and mathematics disciplines.

4.1.3.1.1. Beliefs About Nature of Learning and Teaching

Professional development meetings and interviews reveal rich content about Zeynep's nature of learning. Zeynep has mostly constructivist beliefs about learning and the nature of teaching in STEM education. However, it is seen that, during the research process, she started to change and develop the small number of traditional beliefs she had before. The basis of Zeynep's traditional beliefs about teaching is the assessment and evaluation methods in the Turkish education system and her desire to provide maximum benefit for her students. Under the influence of her contextual beliefs, Zeynep, like Merve and Naz, perceives the integrated STEM model as an area where the constructivist approach can be applied. However, Zeynep sees the integrated STEM model as a field where she will teach in addition to her courses, outside of curriculum teaching, where students can learn by having fun and develop positive attitudes towards STEM disciplines. For this reason, she is of the opinion that assessment and evaluation is not included in STEM education.

Zeynep believes that children are born with the innate ability to explore and wonder and that they discover the concepts in the discipline of mathematics on their own before the start of school. Zeynep's view on learning STEM disciplines also partially reflects Zeynep's beliefs that the discipline of mathematics should be discovered rather than taught. “I think even if we don't realize it, children actually start to explore before primary school.”

She believes children are natural discoverers and explorers of the world around them before their school ages. Unlike Merve and Naz, Zeynep believes that the students are not born with an innate or predetermined mathematical intelligence. Instead, she emphasized that she believed in children's inner learning motivations and development. It is seen that Zeynep changed some of her traditional beliefs throughout the professional development course. One of Zeynep's beliefs, based on her previous experiences, was that solving quick math questions was a success. In fact, in the section of her autobiography related to mathematics and science, where they are expected to describe their achievements in science and mathematics disciplines, they say, “I process quickly.” she does not reply. Also, she emphasizes that students need to develop time management skills by the fourth grade because of exams (The reason why Zeynep says “by the fourth grade” is that student performance is evaluated in Turkey according to scores obtained from exams in fourth grade. In the first, second and third grades instead, student performance is evaluated by teacher observation and student participation.).

> I solved a question the same as this, now it will be the fourth or the fifth time; They also need to learn the concept of time, because this time they can't train in writing in the fourth grade. I spend forty minutes, for example, then I do this; For example, the first twenty people coming to the class. The twenty people first to arrive in that particular time. I'm waiting for you; try it, try it, but I say that after solving a few of the same questions (from initial interview).

On the other hand, this statement of Zeynep also implies she has traditional understanding about problem solving in mathematics lessons. Her process of problem solving consists of posing a problem, asking students to solve the problem individually and checking the answers of students “The twenty people first to arrive in that particular time. I'm waiting for you; try it, try it,”, solving the problem on the white board, “after solving a few of the same questions” then posing the same type of problem again “I solved a question the same as this, now it will be the fourth or the fifth time” and giving limited time for a problem “The twenty people first to arrive in that particular time. I'm waiting for you”.

Moreover, her nontraditional beliefs can be seen in professional development meeting transcripts. On the fourth professional development meeting day, while I was nudging their

ideas about several solutions to a mathematics problem, I challenged their notions of grading related to student learning. I posed a subtraction algorithm and asked them what they would do when a student was swift in solving a problem and answering only with the correct answer.

R: For example, the child marked it. Why do we think this boy marked it?

Zeynep: Naz, he definitely needs to write down the steps. For example, I don't accept that he just ticked the option.

R: No steps.

Zeynep: Yes. In this case, he cannot get points. I say I should see pencil marks on it. So, what did you do?

To better understand Zeynep's answer and reasoning, here I will explain the problem we were discussing about.

I asked teachers what the correct answer of 5-3 was. I designed this subtraction algorithm as a multiple-choice problem. Choices were:

A) 2

B) 4

C) 0

I then wrote a student paper-pen thinking such as:

5-3

3+2

3 + 2

And I asked them what they would be thinking if a student chose 0 after this paper- pen thinking. Zeynep answered this question of mine as: "Naz, he definitely needs to write down the steps. For example, I don't accept that he just ticked the option."

Her response tells us two things; first, she would like to see students' thinking by looking at their written statement. Therefore, a paper-and-pencil work is required. The record of an algorithm is significant for teacher because she would like to examine the process by which the student obtained her/his answer. Also, a record might help Zeynep to locate errors more easily in doing the algorithm, if any. However, her response also tells us her principles might be left behind a student who is swift in mental computation strategies. To be more specific, a student who developed mental computation and estimation abilities must show paper and pen skills to be graded. Moreover, at the end of this discussion, the teachers questioned their own ideas and questioned how they could measure student learning more successfully if they made an assessment for students with different learning levels.

During the professional development course, we carried out studies on the fact that flexibility in performing mathematics operations and being able to perform operations more effectively by using operations in different situations are more important than memorizing and responding quickly to mathematical operations. And in addition, we conducted studies on the fact that students could have different thinking processes and that there could be more than one way to solve a question. It is seen that Zeynep defined student success in STEM disciplines differently at the end of the professional development course.

> For example, one who knows how to solve it in the second way is successful. A child who produces alternatives. Memorizing because some memorize it. He's doing it without faltering, though. For example, I think he is successful if he can produce an alternative way when changing the pattern of the problem.

The interviews made after the implementations show that Zeynep spends more time on conceptual learning and tries to develop different ways.

> I put too much emphasis on problem writing. For example, I give the numbers and ask them to write a problem about it. In this way, I try to understand how they understand that problem. You know, they will write that problem in their own words. I give it much more weight now than before. I saw this as my own shortcoming. (…) Now, for example, we are solving problems right now, I underline the points they consider important. For example, so that they can understand the problem. What do you think are the key points in this problem? What is the part that helps to solve the problem?

Like Merve and Naz, Zeynep also developed important beliefs about the role of the constructivist approach and process-oriented assessment in student success in this study. However, like Merve and Naz, Zeynep also attributed these constructivist approaches to STEM education and envisions STEM education as a model that does not have a kind of assessment and evaluation process and therefore provides a learning environment away from stress and having fun.

> I will continue STEM education if it proves useful for students. I will thoroughly observe them in the process, do they enjoy in that work, do they learn from each other? Are they happy to be in that group, with the group psychology, with that sense of identity, and are they able to add something there? That product that emerged, that problem, that problem at the beginning and the one in the problem-solving process, that is, was that problem finally solved?" (…) You know, because normally, there is something in children, you know, as a result of classical lessons, I will learn this or that, there is a perception like my evaluation with grades. This thought negatively affects children's learning. Since such a thing will not happen in STEM, I am a teacher of the children, if I hear the sentence from the children that we are glad we did it and consequently we learnt this, I will continue.

She believes that students discover knowledge by themselves in integrated STEM education. Additionally, she believes that teachers have new roles in integrated STEM education, which are "guides and observers". Her statement from focus group meeting shows her beliefs:

> Zeynep: In STEM education, the teacher usually does not explain the subject.
>
> R: In that case, how does the student learn?
>
> Zeynep: It's like a door opening another door, it's like one after the other, it's like a chain reaction. When it comes to a certain point, yes, you give information. I mean, it isn't that you don't explain at all, but there is no basic knowledge at first, as in the classical method. In other words, the student kind of discovers the knowledge himself.

According to Zeynep, student-based learning is emphasized in integrated STEM education such as collaboration, metacognition, creating, and problem solving. Besides, she believes that group studies and problem solving are basic requirements for integrated STEM.

> Zeynep: (…) I think learning in STEM education is so different from traditional learning, it is much more useful. In other words, group work is involved, mm, putting your knowledge on paper, planning, what I discovered, what I learned, what problems I encountered, here is the identification of a problem, well, as a result, here is a design, a new product, etc. a very very different stage.

Her beliefs rely on her own experience in professional development course. She said that: "Why… I had so much fun. Frankly, I had a lot of fun for two weeks here."

What's more, interviews with Zeynep revealed that there is a need for updates in teaching, taking into account the new studies on learning and her changing learning profile. Zeynep believes that teachers need to update their knowledge of students and knowledge of content and teaching and professional growth. During the initial interview she stated her beliefs as:

> In my opinion, there is no such thing as the education you receive in traditional schools is sufficient in university. Because necessities of the age, nothing is the same, children 16 years ago and today's children are not the same. Children's learning profiles, your teaching methods, these are constantly changing. Needs, wishes, you need to develop yourself accordingly. I believe the moment you do this; the rest will come. If you constantly improve yourself according to these needs and wishes, you will be successful in teaching. So, you will be up to date.

In summary, the results obtained from the analysis showed that Zeynep mostly has constructivist beliefs about the nature of learning and teaching in STEM education. Her existing traditional beliefs are mostly based on assessment and evaluation methods in the Turkish education system, which are necessary for her students to be more successful. Although Zeynep is a teacher who attaches importance to professional development and is willing to develop both pedagogical content knowledge and content knowledge, the STEM model, which she conceived in accordance with the principles of the constructivist approach, is a field where students can learn, regardless of the curriculum in which she is responsible

for teaching. Zeynep's words about STEM education show this perception: “I think that collaborative work psychology in the STEM model is much better than traditional teaching. So, for example, this is the biggest deficiency in my class, I think I can fix it with group work, STEM, and add positive things to it.”

4.1.3.1.2. Beliefs About Nature of STEM Disciplines

Zeynep has positive mathematics and science identity. She reveals her feelings regarding mathematics and science during the professional development meetings. I raised a question as “When do you think a students’ mathematics and science identity develops and how and why?” She answered this question as: “I've never had any prejudices against math or science. And I saw that I could do it I mean I was aware that I could do it. But, for example, I used to explain a lot to my friends who could not do it in class, especially mathematics. They would be very happy when they started doing it after I told them, I would think that hurray something I knew worked well then."

She acknowledged that she had always been good at mathematics and science. She often helped her classmates to understand topics. She also said that she had never had a negative prejudice towards these disciplines. She describes her own learning experience as traditional and teacher-centered in the mathematics and science autobiography. She remembers how her teachers wrote notes on the black board and they copied what was written on the black board. She also remembers the emphasis was on problem solving in her mathematics education and on doing experiment in her science education.

> I received a traditional education, especially in the primary school part. The teacher would write on the board, and we would take notes. But we used to solve a lot of problems. We had a science lab. We used to do the experiments there. We had an experiment notebook, and we would take notes there. Our lessons were teacher centered.

She thinks her education helped her to be successful during the classes in high school and university entry exams, therefore helping her to get acceptance from the school that she aimed although the type of education was traditional.

> During primary and secondary school, I experienced the results of the infrastructure in these courses throughout my high school education. I was a science student. I've never been challenged. In my last year, I moved to the literature class for my university choices. In the literature class (…), I would listen to the class on behalf of the class and find out what the teacher lacked. I even taught lessons later. (…) While 20 questions would be enough in Turkish-Mathematics classroom teaching, I had 36 correct answers in the exam. No mistakes and it gave me very good feedback. In this way, I entered the first place I wanted in my university preferences.

Her memories about her family reveal that she lacked family support because of socio-economic reasons. Even so, she embraced her own endeavor.

> Zeynep: (…) My mother was illiterate. My father, for example, could not be of any help due to his job. I don't remember anything; I don't remember doing a math or science-style study with my mom or dad. (…) I mean, there is never such a concept, let alone that they help me with my homework. I really did everything myself.

Lastly, she believes professional development is necessary for teachers to increase their productivity, develop an understanding of diverse perspectives as well as entertain teachers.

According to Zeynep, science and engineering are the central disciplines in the integrated STEM education. As she put in order of priority, mathematics comes in the third place. She believes the main theme of the integrated STEM curriculum and the problems in it are related to science. Engineering is related with problem solving. While solving problems, measurements and operations are involved, which represents mathematics disciplines.

It is evident that her conceptualization of the state of science, engineering and mathematics disciplines are in rich educational settings, such as giving examples about the methods used, examples of subjects, relationships between these disciplines. Notwithstanding that, the role of technology discipline has hardly been mentioned. Therefore, I asked for further elucidation of the role of technology in integrated STEM education to have a deeper understanding.

R: Then, what do you think about the place of technology in STEM education?

Zeynep: Well, for example, I am very confused there. I mean, when you say technology, it's like electricity must be involved, right? So, this is a big question mark for us as well. I don't know, but what's the scope of technology? For example, how do we benefit from technology in STEM education at school? Uh, you know, mm, when you are releasing the product, for example, some electrical products, for example, how can I say, now you will stick with a silicone gun. For example, we can use it in the pasting part. For example, we can make use of these when designing lighting, batteries, or products.

As can be seen in the episode above, she has some uncertainty about the definition of technology and use of technology in educational setting. In addition, Zeynep is trying to shape her perceptions of this new discipline according to the context she was in. While questioning the scope of technology and how it can be used in teaching, she prioritizes how it could be used at school. Therefore, I raised the following question about her own point of view. This episode below both describes her uncertainty and paradox about the role of the technology in integrated education and how context limits her perception about this discipline:

R: So how do you see technology in STEM in general, depending on your reading, research, and learning?

Zeynep: What about the technology in STEM, I think there is too much technology in STEM. For example, I think it's not that simple, it's not easy.

Then, I asked for possible examples to see her point of view of the ultimate role of technology.

Zeynep: I mean, I still haven't been able to relate it fully anyway. You know, when we come to where, how much, how it should be, for example, I get stuck, so I wonder how long it was, how it should have been, so maybe I will learn it in time (…)

The findings show that she acknowledged she needed to develop her technological knowledge and instructional technology knowledge. She also believes that she might

discover the ways of implementing and integrating technology into the STEM education during the implementation of integrated STEM education.

Zeynep expressed her beliefs about nature of mathematics and science as these disciplines are abstract both for teachers and students. “I think with mathematics, especially mathematics, maybe they can't think of science all the time, a bit of science is a very abstract concept for us, for children, actually mathematics is the same as well.”

She argues that especially science and mathematics is intrinsically connected with real life. She also believes that students would not develop negative attitude towards these disciplines as they understand these disciplines are linked with real life. “I think that especially mathematics and science are part of life and that there is nothing to be afraid of, uh, they will realize and discover it. I'm waiting for this, for example.".

In the interviews, Zeynep reveals her beliefs associated with mathematics and science. She argues that these disciplines need to be taught in real life context. In this way, she believes they might not be abstract.

> Look, the matter is to relate it to daily life. Mathematics will be associated with daily life. (…) You know, it's not just numbers, it's not addition, subtraction, multiplication, division, it's just mathematics. Or science, you know, this is not the classical perception of what we know, you know, so they should understand that we are constantly intertwined with mathematics and science, apart from such classical knowledge as the buoyant force of liquids.

Considering that a teacher's perspective on mathematics and science discipline plays an important role in determining how he/she structures and teaches the lessons, Zeynep's description of these disciplines without limiting them to operations, numbers and formulas shows that she has a dynamic perspective on these disciplines. It is possible to see the effects of these beliefs on her style of teaching. For example, Zeynep prepared her own lesson plans by reviewing all the sources during her teaching and made very limited use of the textbook. Instead of being completely dependent on any source, she used all the resources and included them in her lessons in line with her goals so that her students could learn these disciplines in the context of real life.

As explained earlier under the teachers' conceptualization of the state of each discipline in integrated STEM category, for Zeynep, technology component is more complicated than they applied in STEM PD. She believes that using electronic gadgets is a part of technology, but not limited to this. Lastly, Zeynep believes engineering is related to problem solving and designing.

4.1.3.1.3. Beliefs About the Context

Zeynep hold the beliefs that Turkish people are not competent in mathematics. During our initial interview, she revealed her already fixed mindset that Turkish people are incompetent in mathematics. In the extract below, Zeynep explains her beliefs:

> "You know, we are a nation that cannot do mathematics." Therefore, because she feels responsible for her students' achievement in mathematics, she says that she focuses more on mathematics during the school year. She believes that she needs to focus on mathematics more than other disciplines because mathematics is a harder discipline and Turkish people are insufficient to be good at mathematics. "For this reason, we put so much emphasis on math in school. We think that science is life itself, daily life, but ı, we do not dwell on it too much, it is the same in life studies. Well, that's why I put so much emphasis on mathematics."

Related to this in her mathematics and science autobiography, she also reveals the idea that students have a negative prejudice towards mathematics in Turkey.

Q: What three concepts or words come to your mind when you think of mathematics and science?

Zeynep replied to this question as: "Prejudice, entertainment, associating with everyday life".

She gave further explanation as: "The students in general have a prejudice. Like fear. They see what they can do when this prejudice is overcome, and they love it."

Second, she believes current movement curriculum and teaching standards in given periods overshadow teachers' autonomy in decision making during the school years. She

believes the curriculum pushes them to chase the teaching standards in limited times and focus on restricted content rather than authentic learning of her students.

> Zeynep: Well, if you look at it from the perspective of the curriculum, it will take one, a whole day for us, so even though we say forty minutes, it would definitely not be like that. Well, if you consider STEM applications, it will take a whole day. When you look at the curriculum, this is a time constraint because there is a curriculum that you must cling to.

Similarly, Zeynep believes that the requirement for using teacher's guidebooks in the lessons limits teachers' ability to implement authentic and effective learning of her students. She adds that students' feedback shows the lessons in teacher's guidebooks contribute less to students' learning and motivation when she implements what is written in the guidebooks.

The following excerpt from professional development meetings shows her beliefs:

> "The absence of a guide gives the teacher some leeway. We don't use it in other classes anyway. Look, we have only one Turkish language, ask personally, I have to read only when I ask questions to children there." (She refers to an obligation as teachers in Turkey need to use the books given by the Ministry of Education) Apart from that, we don't use that guidebook. I mean, I sometimes write notes there to see what's missing, in case they want it at the end of the year. (She refers to the review report required from teachers by government at the end of the academic year.) "But other than that, as she said, you teach according to your own imagination."

She added on this during our interview and gave an example from her own kid as her own student in her classroom. Zeynep stated, depending on her interviews with her 3rd grade daughter, that the daughter couldn't learn enough when the teachers only used the textbooks in their classes and that these lessons were inefficient, and they felt that these lessons were not useful for their students when they teach in such a way.

> "I know this because I am both a teacher and a mother - because I have a child attending school. For example, when my daughter comes home and comments on her teachers, she says that she worked with that teacher, but I am happier with that, so how

can I say, then I have more trouble. She says she didn't learn anything. I do not feel comfortable. You know, as you said, you must cover those activities in Turkish, which means that when I do this, the children think the same way about me as well. I feel more discomfort."

Zeynep also emphasizes how professional development is undervalued for the public-school teachers in Turkey. She believes most of the educators have assumptions such as professional development courses are for private school teachers and public-school teachers attend professional development courses only if the state forces them to do so or they have funding other than themselves. She explains her beliefs as:

Merve: They think it seems extra that public school teachers do something related to professional development a little bit.

Zeynep: One point is that you cover the cost yourself, the state doesn't oblige you to do this, you allocate your time and money voluntarily and you don't actually have to participate at all. (…) The teacher in the private school is sent to the seminar, for example, the school welcomes him, but there is no such thing in the public school.

Zeynep also criticizes top-down interventions in Turkey, and she believes that the system is incapable of effective applications.

"We see something, we try to do it right away, then you say it didn't work, then yes you change it. (Speaking of the Ministry of National Education) In the education system, private schools usually lead the way. I mean, they see something in private schools, okay? In their advertisements, for example, they see the first STEM there, they see the smart board application there, then they see the coding there, they say, let's do it in mind games, let's do it, but they have no infrastructure, they don't let the teacher train on this subject, the teacher in the private school he is sent to a seminary, for example, the school welcomes him, but there is no such thing in a public school."

Zeynep also believes that teacher education is too subjective and insufficient to meet the teachers' needs. She believes that universities as the institutes that prepare their students as future teachers are responsible for preparing Turkey's teachers poorly. Her belief relies

on her experience. She alleges that most of the universities are located in city centers and all of the student teachers have experience with students in downtowns. However, most of the teachers are assigned to the rural areas especially in their first years of professions. Therefore, teachers lack preparedness. In Zeynep's view, teachers of education are insufficient to prepare their students and to address the students with diverse cultural backgrounds and different income levels as well as those students whose second language is Turkish. Her beliefs were revealed as Zeynep and Naz were discussing and reflecting on their own teaching. The next episode shows Zeynep's beliefs regarding teacher education in Turkey:

Naz: How was the university?

Zeynep: Naz, it was nice, nice; actually, studying in Istanbul, the student profile of the education faculty was mixed. But we always had something like this, Naz; We took a course called education in the informatics class, but there is no informatics class anywhere. (…)

Naz: Yes, where did you teach?

Zeynep: I was appointed to Mardin Kızıltepe in the first year. I think all my life, there is Trabzon, Istanbul, I'm going east from Istanbul, I don't know where Mardin is on the map. The culture is different, you have a language problem, we were appointed to a school whose foundations were laid and under construction (…) something like this happened Naz, I never forget I told children about skin cleaning, skin means door in Kurdish. We must clean our skin every day, wash our hands and face, wash and clean our skin every day. One day I will never forget, someone came to the door and wiped the door of the classroom persistently, the children wiped the door of the classroom with cloths in their hands. I said guys, why are you cleaning the door? They said, our teacher you said that. I did not want such a thing from you, but you told us to clean it every day; he was talking about the classroom door. So, it is necessary to use a common language. It has been a very different journey for me. (…)

According to Zeynep, there is a big difference between teaching in real life and teaching at the education faculty, and the information given during university education is given

considering certain parts of the country, but this information does not prepare the teacher to be a teacher all over the country.

Zeynep further explains her beliefs about the subjectivity of teacher education in Turkey as:

Zeynep: And you know what, when you graduate from university, you don't know much about what you will encounter, even coming from there. Look, for example, you studied in Istanbul, you did your internship in Istanbul, so Kadıköy district in Istanbul and this region of Ümraniye are not the same. You know, you don't know what you will encounter in the system. Okay, you are given an education, but it is actually in the best conditions, so now you know that education is given to you. (…) That's why there is such a problem in the system. Nor are they fully prepared to be teachers all over Turkey.

In summary, Zeynep believes that the Turkish education system does not prepare teachers to teach in their professional lives in accordance with the conditions all over the country. According to this belief, which she developed based on her own experiences, she was generally prepared to teach in schools with good conditions at university, but she worked in schools in low socioeconomic regions with different cultures and faced various difficulties. On the other hand, Zeynep believes that when her students come to school with a fear of mathematics and when she explains mathematics in relation to their life, students will develop a positive attitude towards this lesson. In addition, Zeynep states that she believes more mathematics courses should be offered at school, since we are not sufficiently successful in mathematics in our country. Zeynep, like other participants, believes that professional development is not sufficiently supported and valued by the state. And in addition, Zeynep believes that the curriculum that she is currently responsible for will be an obstacle to her application of innovative methods.

Zeynep believes families to be insufficient in supporting their kids' learning in a way that they construct their own knowledge. She expresses her beliefs as:

Zeynep: What comes from home is ready. Homework is done on behalf of the student. And they don't think of it as doing the student's homework; they think of it as helping him.

According to them, it is support for the mother to do this. She thinks that doing it on behalf of the child is like helping. So, she thinks as help and decides on his behalf.

For the sake of readers' understanding, it is important to mention about teachers' understanding of "two categories of techniques". Two categories of teaching strategies are revealed as teachers discuss about community support. The first category consists of hands-on learning experiences. Teachers refer to this technique when they say "etkinlik" And the second category consists of pen and paper techniques. Mostly, it requires students to copy what is written on the board.

Therefore, Zeynep believes that family support is missing if teachers would like to use hands-on techniques or any other technique which is not under the second category.

> Zeynep: The parents want the teacher to make the infrastructure of my child strong. They say forget about activities etc. They say their child can solve questions quickly, they say he should not fall behind his peers.
>
> R: So, how do you think parents think that learning with activity will contribute to students?
>
> Zeynep: They question the contribution of the activity to the child, that is, they think that it it doesn't contribute much. You know, if you can tell the parents that that activity has turned into learning, they accept it, but otherwise they see it as a waste of time.

On the other hand, Zeynep believes that the art of teaching is related to understanding the community's culture. Moreover, she states that teachers must know the cultural codes of the current community and should use a common language. She believes that culturally reflective pedagogy has an important element in effective teaching; therefore, she values communicating with students' families. Her beliefs come from her past teaching experiences in the eastern part of Turkey where the community has a different culture than she does.

Zeynep believes that limited materials and lack of technology laboratory prevent teachers from implementing innovative methods. She believes that the lack of materials forces teachers to use traditional methods in their classrooms.

> Look, maybe we will be like that in years to come. Look, do you know what's going on now? For example, let's say I'm doing multiplication today, okay? For example, I immediately take notes like this, or take notes on the phone or something. I'm making a note, look, Zeynep, you will teach this tomorrow, bring this from home, or you will do this in class to prepare for that, okay? So, if you don't get this, you can forget about it later, or you can't just collect some things from the school's surroundings and put them in. Everything is not at your disposal in the classroom, so there is such a problem. Maybe that's why these people feel the need to act according to the guideline. Because step by step it tells them what to do.

According to Zeynep, physical inadequacies at school cause the teacher to follow the guidebook more strictly over time, and therefore active learning is avoided. In addition, teachers who want to teach with effective methods apply for the support of their parents because they cannot get enough support from the school. However, the experiences of parents that they can't get financial support also push teachers to give up on these methods over time.

> We can think like this, there are parents who say what the benefit is and prefer that system (traditional learning) more. Why is that? Because, for example, we want a lot of materials from the children for the STEM activity, and their order is broken, financially.

As can be seen, Zeynep also thinks a lack of material puts teachers in a hard position in front of the families. Therefore, she believes schools' physical conditions have an important effect on teachers' choice of educational techniques. On the other hand, Zeynep reports that big class size has a negative effect on teachers' implementations. Her belief about class size didn't change after the implementation was completed.

Zeynep believes her students' ability and competency requires more than the given time in school. Her explanation during the interview regarding time management in integrated STEM education reveals her beliefs:

> Well, such a study takes one, a full day for us, so even though we call it forty minutes, it is definitely not like that. Now, if you take into account the environmental factors, the perceptions of the children here, it takes a whole day.

On the other hand, Zeynep states that students have prejudices about mathematics and science disciplines and that these prejudices were formed before students started primary school. “Children have a general prejudice, like fear. I believe that when this prejudice is overcome, they will see that they can do it and they will love.” During the research, Zeynep developed ways to help students overcome their existing negative prejudices. For example, Zeynep states that she thinks it is important for students to develop positive attitudes and that she will progress by evaluating the feedback from the students in the STEM modules she is developing. In addition, Zeynep states that it is necessary to make lessons related to their lives in order to change students' beliefs that mathematics and science are difficult in STEM module applications.

> (…) And I think that people learn more easily by having fun. I mean I believe more in this. In other words, it is not permanent if you memorize a piece of information. Students enjoy learning while having fun in Math and science. Learning becomes permanent when they discover when and how it will work for them.”

Zeynep also developed an understanding after attending this study as students develop an in-depth understanding while learning in group, solving problems, and developing products. On the other hand, Zeynep believes that after STEM modules, students developed positive attitude regarding mathematics and science.

Zeynep believes effective instruction requires teachers to develop professional knowledge. Zeynep’s beliefs about teacher context show that professional development is needed for teachers. In the age of information and technology, emerging knowledge and skills have changed. Therefore, students have new abilities, approaches, and concepts in terms of information, communication, computer, and technology. Teachers must take these changes into account. According to Zeynep, professional development is needed to learn the new forms of knowledge and competences, and to change the pedagogy. In the interview, this was expressed by Zeynep as follows:

> In my opinion, there is no such thing as the teaching, yes, the education you received you received in traditional schools is sufficient. Because the necessities of the age, the children 16 years ago are not the same as today's children. Children's learning profiles, the way you teach the lesson, these are constantly changing. Needs, wishes, you need to develop yourself accordingly. I believe the moment you do this; the rest will follow.

Zeynep also believes that teachers have biases towards competent students. While our discussion topic was assessment, teachers noticed that multiple choice questions didn't allow them to track student progress often. Furthermore, Zeynep raised a question if teachers had bias towards students who came from different classroom performance even when they marked the same options.

The following section explains Zeynep's concern regarding teachers' fairness while using multiple choice exams:

> Gamze wrote rhythmic counting in the notebook and said, she wrote, start from 4 and count up to 40, four by four. However, Gamze asked them to write on the paper starting from 4. But when she said, "count as an expression", a student left it blank. He counted it silently again. Then Gamze calls him, a successful student; why did you leave this blank? My teacher, he said, I did not quit. How so? E you told me to count, I counted in my heart, so he said.

As can be seen in the episode, Zeynep noticed that multiple choice exams are inadequate to observe students' progress. She also reveals her beliefs about teacher context. She believes that teachers' decision making may be affected by students' classroom performance.

Lastly, Zeynep believes teachers have limited ability to distinguish mathematically competent students. She is of this opinion for two reasons. First, she thinks two types of mathematics exist: (1) real mathematics, (2) school mathematics. According to her, the number of the students who are good at real mathematics is very low. The students whose teachers think that they are qualified in mathematics are the students who are good at only school mathematics. Even if there are students who are very skilled, teachers have no ability to discover these students. She believes in this education system; teachers are too unqualified

to evaluate students' achievement in real math. She thinks that way because teachers are inadequate in content knowledge in Turkey. She expresses her beliefs during the professional development meetings as:

> Even the children we see as very successful in mathematics are actually very successful children in taught mathematics. I mean, you said that there are some people, you know, whatever side of life they look at, they see it as mathematics. We have almost none; even if we do, we don't notice. Because we do not have such a potential in the sense of discovering it. So those kids are very different kids. Here are the kids who are the best at taught math within the limits of our own knowledge. Actually, there is such a limit. We do not have the potential to measure it. I do not have such a potential in my country, that is, in my environment, in the education system, there is no evaluation system that has the potential to measure that mathematics.

4.1.3.2. ***Pedagogical Content Knowledge***

The results obtain from the analysis showed that her knowledge of STEM education has improved, and this is reflected in STEM education practices. Data revealed that Zeynep frequently includes strategies that will enable her students to learn actively, especially in her first lessons. The implementation of many new teaching strategies, which she had never applied before, within the scope of this research, is seen as a contribution of the applied professional development course. However, it is seen that Zeynep applied more teacher-oriented teaching strategies in her later lessons due to the situations related to classroom management. It is seen that Zeynep focuses on the problem-solving skills of her students, especially within the scope of STEM education, but it is seen that she frequently resorts to traditional methods to develop these skills.

The findings showed that she has mastered the curriculum outcomes and changes. She has included the outcomes that will address the different cognitive stages of her students in her lesson plans. She has determined STEM modules in parallel with the existing curriculum. Zeynep has built her new lesson plans on the past knowledge of her students and has applied the socio-cultural backgrounds of her students as a source while preparing her lessons. During the research, Zeynep developed her knowledge about the purpose of assessment and

evaluation and had the opportunity to improve her skills in using different assessment and evaluation methods. Unlike other teachers, Zeynep aimed to benefit from technology within the scope of this research and tried to integrate it into her lessons. However, she ignored the discipline of technology in her later lessons, as inadequate environmental conditions prevented her from reaching her goals while applying her lessons. In addition, Zeynep adapted her 21st century skills, especially collaboration and problem solving, and included them in her applications. Although Zeynep did not include the standards of the engineering discipline in her lesson plans, she partially benefited from this discipline in her classroom practices. Zeynep states that working in collaboration with other teachers in the professional development course within the scope of the research is beneficial for the development of pedagogical content knowledge and pedagogical beliefs. She also states that carrying out both theoretical and practical work contributed to increasing her motivation. In the next section, Zeynep's PCK is analyzed in detail in the sub-steps.

4.1.3.2.1. Knowledge of Teaching Strategies

Zeynep’s knowledge of teaching strategies is analyzed under two components; first, knowledge of subject-specific strategies; second, knowledge of topic-specific strategies.

Zeynep’s knowledge of teaching strategy is analyzed based on the interviews, lesson plans and observation of lessons. Her knowledge of instructional strategies and instructional representations are also analyzed in this section. During the implementation of STEM modules, she used several *subject specific strategies*. When Zeynep's knowledge of subject specific strategies is examined, it is seen that she mostly included strategies in mathematics and life sciences and partly in engineering disciplines. The subject-specific strategies that Zeynep included in her lectures are generally teacher-centered. The student-centered methods she used are mostly those she experienced during the professional development course within the scope of this research. Although Zeynep tried to design her lessons in a student-centered way, she gave weight to teacher-centered methods, thinking that her students could not learn well enough in the application process due to environmental conditions such as class size and inadequacy of students' readiness. Zeynep did not include instructional strategies related to the technology discipline in STEM modules. The reason behind this is that the environmental conditions arising from the school do not make it possible for her to teach about the technology discipline.

Zeynep designed her modules assets of 6 lessons. During the implementation of the modules, she modified her lessons according to the observation of her students' needs. Zeynep made these decisions according to her observations and students' oral answers to the questions.

In the first module, Zeynep started her first lesson by using 3-act-modeling method. Zeynep wanted to link this lesson with her students' former knowledge about weddings. Additionally, she wanted to make a connection between the objectives of current lessons and students' body of knowledge. She started 3-act-modeling method by presenting images of weddings. Then, Zeynep posed these questions: "What do you notice?" and "What do you wonder?" By posing these questions, Zeynep aimed her students to pose a problem to solve. Then, with the participation of students, Zeynep posed a word problem: "There are 20 guests in the ballroom. As a host, you must arrange a seating plan where each table has 2 guests. How many tables do you need?" She also wanted to attract her students' interest while solving a word problem. As Zeynep used question-answer method, she noted students' answers on the blackboard. Then, she handed out problem solving worksheet and made students note their possible solutions to the worksheet. Then, Zeynep used think-pair-share method to make students change ideas as they worked in group. She also introduced the microphone method to eliminate inequality in the groups. However, preliminary experiences of students, which are pre-requisite for the group study, restrained students from actively engaging with the tasks based on her observations of groups. Therefore, Zeynep re-defined the task for students and made changes in the lesson plan. Zeynep decided to use question-answer method instead of group study and think-pair-share activity. During this newly designed lesson, Zeynep focused on students' understanding of problem. While students answered Zeynep's questions about the problem, Zeynep noted students' answer on the black board. Zeynep used such a structure as: "What is known?", "What is asked in the problem?", "What is going to be answered?" When Zeynep discovered her students needed more support to grasp the idea of division, Zeynep asked her students to act. She made students solve the problem by acting in the classroom. Therefore, Zeynep used smaller numbers to show the solution to the problem. She asked 8 students to sit by 2's. Afterwards, Zeynep opened a discussion about possible solutions of the problem. Then, the students were asked to solve the problem by using manipulatives individually. Next, the students were

asked to answer the problem in worksheet. Subsequently, Zeynep asked her students to share their solutions with each other. Zeynep also wanted her students to share some of the ideas with the whole classroom. Then, Zeynep took notes of the students' answers on the blackboard. Zeynep challenged her students to find another solution to the problem. Her aim was to develop a deeper understanding.

During the second module, Zeynep mostly used question-answer method. While using this method, she expected her students to answer her questions by getting permission from her. She used 3-act modeling as well in this module. She started with presenting the views that the students were familiar with from google maps. However, this activity was interrupted because of the poor internet connection. Then, she used the images, the screenshots of which she took from google maps, in case there was a lack of internet connection. She attracted students' interest by presenting them several places they knew, such as their school, the streets where students lived. She used the objectives from life sciences and students' body of knowledge as a context of the mathematics problem. Zeynep had a student from Syria in her classroom. Her student had difficulties in expressing himself in Turkish largely due to Turkish being his second language. Zeynep aimed to increase her students' participation in the classroom. Meanwhile, she used the current socio-political issues in Turkey as a context of the lesson. Therefore, she created a story that involved the idea of helping Syrians during the Ramadan by sending them food aid and building a bridge named "Love Bridge" between Turkey and Syria. She used Google maps to present satellite images of the two countries and their locations with respect to each other. She started with Istanbul in the google maps. By zooming out the map, Zeynep showed all the neighbors of Turkey to the students. Then, she told the story she made up. Then students posed the word problem. "Engineers will build a bridge between Turkey and Syria to send food aid to the Syria by the end of the Ramadan. If the bridge is 40 meters, and engineers plant trees on each side of the bridge 5 meters between each, how many trees will the engineers need?"

By giving them concrete materials, Zeynep aimed to motivate them to work collaboratively and solve the problem as a group. Then, Zeynep gave students worksheets to work individually.

To sum up, the main characteristic of Zeynep's teaching was mostly teacher centered. In the meantime, Zeynep allowed her students to share their ideas frequently by answering questions, and in certain times she made her students work collaboratively to solve problems.

Teachers' knowledge of *topic specific strategies*, teachers' understanding and use of the effective strategies for specific STEM topics including strategies to engage students in inquiry along with knowledge of real-world STEM related connections representations are analyzed in this section. The analysis of the data shows that Zeynep used strategies for her students to understand the problem in word problem solving, which requires only four operations in the discipline of mathematics, and she wanted these strategies to appeal to students at different cognitive levels in the solution of the problem.

Zeynep employed problem solving methods and she highlighted students' difficulty in understanding the word problem. She used a chart with an explanation of the parts of the problem. She explained the word problem in three sections. (1) What did you notice? (2) What do you wonder? (3) What is the definition of the problem? Then by using question-answer method, Zeynep redirected her students' attention to the possible solutions of the problem. The students noted their possible solution methods on the white board. Then, the students were asked to solve the problem by using problem solving worksheet; afterwards, Zeynep showed them the solution to the problem.

In the second module, she utilized the problem-solving method. In this module, by using a white board, Zeynep explained the word problem to the students steadily. She explained the word problem to the students under 5 subcomponents. These are characters, location, time, case, and result. After explaining the problem, Zeynep also explained different ways of solving it. Zeynep utilized several methods. In the first method, she focused on division box. In the second method, she focused on skip counting method. Zeynep related division operation to subtracting. Zeynep started from the divisor; by counting 5's, she reached out 0. Then with students they counted how many times subtraction operation was carried out. In the third method, Zeynep used skip counting method starting from 0. In this method, Zeynep utilized a representation of the model. Zeynep counted until 40 for each side of the bridge, and then with students she counted how many trees would be planted. In the fourth method, Zeynep used direct modeling by drawing two parallel lines as a symbol of the bridge

similar to the strip diagram. Zeynep used her drawing to symbolize trees. By counting the symbols of the trees, she came up with the answer.

The analysis of the video transcripts of the Zeynep's lesson reveals that Zeynep has sound knowledge of topic-specific strategies to teach word problems and division problems. On the other hand, when the topic-specific strategies used by Zeynep are examined, it is seen that she especially focuses on the students' understanding of the problem and focuses on the discipline of mathematics in her lessons.

4.1.3.2.2. Knowledge of Curriculum

Zeynep's knowledge of curriculum related to topics she included in her STEM lesson plans was investigated. Her knowledge of goals and objectives, including what students learned and how they would learn afterwards, knowledge of specific curricular programs and materials such as activities and materials is analyzed in this section. Zeynep's knowledge of curriculum about topics she included was evaluated with the help of professional development meetings, lesson plans, classroom observations, interviews, and her reflections.

In general, it is seen that Zeynep is knowledgeable about the outcomes and changes in the curriculum; she addresses the different cognitive stages of students in mathematics and life science disciplines. She does not include the standards in technology and engineering disciplines in her lesson plans, but she partially includes the teaching of the learning outcomes in these disciplines in her lessons. In the preparation stage of the lesson plans, the effects of environmental factors are seen. It is seen that while designing her lessons, she chose the learning outcomes in parallel with the curriculum and took the socio-cultural and geographical contexts of the students into consideration.

When the data are analyzed, it is seen that Zeynep followed the developments in the up-to-date curriculum and knew the subjects and standards in the curriculum for which the teachers were responsible. Zeynep prepares reports on the curriculum requested by the Provincial Directorate of National Education every year, leads the studies at her school, and the reports she sends represent her province and district in the Ministry of National Education. At the same time, Zeynep stated that during the professional development meetings, the guidebooks given to the teachers were not up-to-date, and that the teachers had

to evaluate the information here by examining the curriculum. While explaining this thought, she also explained the changes in the fields of Mathematics and Science, which changed according to the previous years, with the subject titles and achievements. As it can be understood from here, Zeynep has deep knowledge about the curriculum.

On the other hand, when the lesson plans prepared by Zeynep are examined, it is observed that, just like Merve, Zeynep tried to include the subjects and achievements in her lessons in accordance with the timetable in the curriculum she was responsible for in the Life Sciences and Mathematics lessons. And again, like Merve and Naz, it is seen that she didn't include technology standards in her lesson plans. It is seen that the lack of a curriculum for primary school provided to teachers by the Ministry of National Education and the lack of learning outcomes play a role here.

However, although Zeynep did not include it in the lesson plan, it is seen that she made an effort to include technology standards in her lessons. Although she tried to include technology standards in STEM applications in the beginning, it is seen that she did not include them in other courses due to school-related factors (slow internet, limited access of students to technological tools, etc.).

4.1.3.2.3. Knowledge of Student

In this section are presented the requirements of students to learn the upcoming STEM module, students' conceptions of particular topic, learning difficulties, motivations, diversity in ability, learning style, interest, developmental level and need, and students' conceptions, learning difficulties.

Zeynep's knowledge of students' requirements for learning was evaluated with the help of interviews and lesson plans and teachers' reflective journals. The analysis of Zeynep's lesson plans, video recordings of her lessons and reflective journals reveals that Zeynep's knowledge of students is based on her students' background and preconceived knowledge.

Zeynep took into consideration her students' preconceived knowledge while preparing her lesson plans and built the learning objectives in the lessons on the previous learnings. For example, in the first module, Zeynep asserted that each student needed to know skip counting, multiplication and solve "2 x 10=10 x 2=20" equations prior to learning division

and they must be able to establish the sharing and division relationship. Zeynep stated that in the previous life sciences lessons, topics such as concept of neighbor, “describing the location of our house”, “the position of our classroom in the school” had been covered. Therefore, Zeynep focused on the neighboring countries of Turkey.

Zeynep put a lot of emphasis on students' understanding of problems in STEM modules, as she thought that her students might have difficulty understanding the problem while solving mathematical problems. According to Zeynep, in the word problems, students must know what information is required, what information is not necessary and what is being asked. To be able to understand word problems, students need to develop their reading comprehension skills. Problems should be read carefully, and students need to understand how the given information is related to the solution of the problems.

Zeynep used the culture in which her students lived and the experiences they had while forming the context of her lessons. She also enabled students to construct broader meanings on concepts they knew (such as neighbor, neighboring country).

Zeynep states that henna nights are one of the common traditions of our culture. Children have attended them many times and they are aware of this tradition both in their families and in their relatives’ lives. Therefore, this topic has been selected with the aim of drawing attention to a cultural heritage element from daily life connected with children’s experiences and having more opportunities for students’ interpretation about the subject.

When we look at Zeynep's lessons, it is seen that students' learning difficulties rarely came to light. In such cases, Zeynep tried to get her students to find the right concept with the question-and-answer method. During the second module, when students are asked how to give the directions to their classroom, students used the words such as across, opposite. To help students to find the correct concepts, Zeynep posed several questions. However, students had difficulties defining the location of their classroom by using 4 directions. Then, Zeynep indicated the words, North and South.

The lack of data on concepts such as students' learning methods, learning difficulties, and students' developmental levels is also related to Zeynep's inability to use methods that

emphasize students' learning. The development of the students could not be observed in depth as they were usually taught in traditional ways.

4.1.3.2.4. Knowledge of Assessment

Zeynep's knowledge of assessment, including knowledge of methods of assessment that includes knowledge of specific instruments, approaches or activities, knowledge of what and how to assess, teachers' use of formative, summative or diagnostic assessment, is analyzed in this section. Zeynep's knowledge of assessment was evaluated with the help of interviews, lesson plans, video records of lessons and teachers' reflective journals.

The analysis of the data shows that, during the research, Zeynep's perceptions of STEM education and, accordingly, of the purpose of assessment and evaluation changed. During the process, Zeynep had the chance to develop and apply her knowledge of the formative assessment approach.

Zeynep's knowledge of assessment and evaluation is in parallel with Zeynep's perception of integrated STEM education. Before the research, Zeynep saw the integrated STEM model as an area where she would teach, in addition to her curriculum, outside of curriculum teaching, where students would learn by having fun and develop positive attitudes towards STEM disciplines. For this reason, she thought that assessment and evaluation was not included in STEM education.

After the studies on STEM education in the professional development course, Zeynep stated that she believed it would be beneficial to use a formative assessment tool as a better way of observing students' learning.

The analysis of data reveals that Zeynep hypothesized there was a difference in assessment between traditional teaching and integrated STEM education. According to this changing conception, it is seen that Zeynep perceives formative assessment as a assessment and evaluation approach specific to STEM education. When designing STEM modules, she aimed to assess students' ability to pose a problem, their problem-solving plan, and their designs along with their collaborative learning. Additionally, she decided to use unstructured

observation as an assessment of modules (Roeber, 2002). An excerpt from the interview that reflects her assessment goals is presented below:

R: So, what are you planning to measure?

Zeynep: What will I measure, the process?

R: What do you mean by process?

Zeynep: One, problem determination. Look, I think that's a very important thing. So it is very important to be able to identify the problem. Then about that problem, you know, uh, how can I say it… You know the trend. I mean, you know yourself…, for example, here's the first one, it's the same in planning, you know, what we're going to do first, what's in the second stage, in the form of the third stage. (…) That work within the group, that unity. I'll look at that. It is also useful to evaluate the product that comes out, so I think it needs to be evaluated, after all, when you look at it (STEM), it's like a work entirely aimed at it. At the end of the road, there is an impression as if it had to be. That product which came out, that problem, that problem at the beginning and the one that was in the problem-solving process, that is, was that problem finally solved? That's why I rate it. (…)

R: You said that if you believed it was useful, you will continue. For example, what should you see to think that, yes, it is very useful, I must continue from now on? What's the indicator, the thing that will show you that thing over there?

Zeynep: The process. I'm totally going to observe them there, I mean, there, uh, in that work, are they enjoying, uh, are they learning from each other? Is he happy to be in that group with the group psychology, with that sense of identity, and is he able to add something there?

As seen, Zeynep stated that in STEM education, students' problem identification, solving, collaborative skills, product design and students' attitudes should be measured. She stated that she wanted to improve herself in order to better observe students' learning in the STEM module application process and worked to improve her skills in using formative assessment methods. Zeynep employed her knowledge of assessment to create formative assessment tools. She created problem solving worksheets. She used problem solving

worksheets throughout her teaching sequence. Problem solving worksheets consisted of different questions for each module. The images below indicate the problem-solving worksheets for each module (see Figure 4.5 and Figure 4.6).

Name:	
What did you realize?	What do you wonder?
What is the problem in this case (defining the problem)	What information do we have that can help solve this problem (uses the given to solve the problem)?
What is your guess?	What is your solution?
How else would you solve this problem?	Compare your guess and the result.
Show your solution on the model.	What other example you can give about our cultural heritage?

Figure 4.5 Formative Assessment Tool Created by Participant Teacher

Worksheet

<table>
<tr><td colspan="2">Fesah and his friends collected aid for their relatives living in Syria due to the approaching Ramadan. These aids will be taken by trucks to our Hatay province, which is a neighbor of Syria. A bridge of aid and friendship will be established from Hatay to Syria. Trucks will cross this bridge and deliver aid to those in need in Syria. The engineers who built the bridge have a problem. The length of the bridge is 40 meters. They will plant trees 5 meters apart on both sides of the bridge. They cannot find out how many trees they need for this. Can you help them?</td></tr>
<tr><td>Write your estimate.</td><td>Write your solution.</td></tr>
<tr><td>Your 2nd solution</td><td>Your 3rd solution</td></tr>
<tr><td>Which solution would you prefer to use? Why?</td><td>Can you compare the results of the solutions?</td></tr>
</table>

Figure 4.6 Formative Assessment Tool Created by Participant Teacher

As can be seen in the images, she aimed to assess students' several problem-solving methods, students' estimation, students' understanding of the given problem, and their knowledge about cultural heritage which was the context of the problem. Zeynep decided to use open-ended questions to assess students' knowledge. She aimed to comprehend students' thinking in problem solving from a broad perspective. Although Zeynep didn't measure every skill (problem identification, solving, collaborative skills, product design, and

students' attitudes) that she considers important in STEM education, Zeynep implemented her knowledge of what to assess and how to assess in line with her intention.

4.1.3.2.5. Knowledge of Context

Techers' knowledge of context of teaching including who they teach, where they teach, what they teach is analyzed in this section (Feldman & Herman, 2015). Zeynep's knowledge of context was evaluated with the help of interviews, lesson plans, video records of lessons and teachers' reflective journals. Zeynep used her knowledge of context with regard to community, school and country conditions in several stages of her implementation such as planning, reflecting and establishing objectives.

It is seen that Zeynep's knowledge of context had an impact on her teaching. While school, country, and context knowledge about the student's cognitive readiness had a negative impact on her teaching, the knowledge about the student's context had a positive effect and contributed to the arrangement of the subjects in a way that was related to the students' lives, interests and experiences.

Zeynep considered that the current community she had been teaching for several years lacked support to students' learning in school. Accordingly, all learning activities took place in school. Zeynep did not plan homework due to the lack of family involvement in the community.

Zeynep also considered that grade year had an effect on her students' learning. She stated in initial interview that "Umm, so now if you're looking, uh, now our class is the second grade. I'm looking to see if they can turn it into an incredible engineering design cycle. So probably nothing like that will come out of us so much." During the implementation, she created one lesson plan out of twelve lesson plans that included engineering design process. According to her, students were not able to complete the design and there was a tendency for some students to manifest passive withdrawing behavior. Other drawbacks identified by Zeynep were that students' listening comprehension was low and that they focused on finding the correct answer instead of developing conceptual understanding. In addition, Zeynep stated that in her classroom she had several disadvantaged students, that being said, students had reading difficulties.

“They tried to build a bridge. But they couldn't finish it in time. It took a long time to implement the lesson plan. They could not manage the group work correctly and actively. For example, I was very disappointed with that plan. I had trouble with the children and the process. For a while, I even started to think that STEM didn’t work in my classroom at all. There are many disadvantaged students in my class. In addition, children's ability to listen to the instructions and act accordingly is very weak in the process. They are wholly focused on the result. Their aim is directly to find the answer to the question.”

Additionally, Zeynep considered that her school had no laboratories, and her classroom was lacking in learning materials such as blocks, rekenreks, and manipulatives. Therefore, Zeynep’s knowledge of context in regard to school limited her use of materials and she used recyclable and easily accessible materials. She used technology only for monitoring Google maps and images. Zeynep’s knowledge of context had an effect on her choice of methods. For example, Zeynep stated that her class size would not allow her to implement group studies efficiently. Data analysis indicated that Zeynep mostly used teacher-centered teaching strategies in her implementations. Zeynep used her knowledge of context in regard to conditions of country. She integrated her lesson plans with the current curriculum. She followed the mandatory curriculum to decide on which standards to use in her lesson plans. Zeynep stated in her reflective journals that if internet connection were better, she might use the Google maps more efficiently. In addition, she reflected on one of her lessons that due to the high number of students who did not come to school that day, lessons were more efficient.

Zeynep used her context knowledge to create lesson plans which were connected with students’ lives and their cultural background. In order to create lesson plans which were relevant to learners, Zeynep used the “neighbor” and “wedding ceremonies “concepts. In each module, Zeynep started lessons with the elements in her students’ lives, and then widened the meanings of the concepts. For example, in the first module, Zeynep first focused on how her students experienced the wedding ceremonies by sharing their ideas with each other. Then, she focused on some special events in the wedding ceremonies. She presented images of henna nights. Students were asked what they noticed by looking at these images, and what they wondered. Moreover, in the second module, Zeynep started to show the satellite images of their own neighborhood, and then she widened the view of students by

presenting them their cities' images and their countries' images, and their neighboring countries' images. It was observed during the lessons that students were attracted by having elements from their own lives in the lessons.

To summarize, Zeynep used several components of her students' lives to make lesson plans relevant to her students. Additionally, she built lesson plans on her students' body of knowledge and culture to create more intellectually educational experiences.

4.1.3.2.6. Integrative Thinking

Teachers' knowledge of integrative thinking along with different approaches of integration such as content integration and context integration has been studied (Roehrig et al., 2012; Stohlmann et al., 2013). Zeynep's integrative thinking was evaluated with the help of interviews, lesson plans, video record of lessons and teachers' reflective journals.

The analysis of lesson plans and reflective journals revealed that Zeynep implemented her integrated STEM modules as context integration. She concentrated on mathematics, and she utilized objectives from life sciences as a context. While she did not involve engineering concepts or objectives, she utilized technology to show videos and images. While Zeynep focused on the mathematical objectives such as division, students did not require the explicit use of life sciences and technology content to solve the problem. Initially, Zeynep had planned to use engineering concepts such as working as a team or constructing prototype, but after trying one lesson, she excluded these objectives from her lesson plans due to the classroom management issues.

To sum up, Zeynep used context integration where she centered mathematics objects; she did not focus heavily on the objects from life sciences and technology.

4.1.3.2.7. Knowledge of Technology Integration

Teachers' knowledge of integration of technology to enhance instruction of specific STEM topics in meaningful and appropriate ways to promote key students' outcomes is analyzed in this section. Zeynep's knowledge of integration of technology was evaluated

with the help of interviews, lesson plans, video record of lessons and teachers' reflective journals.

The analysis of the data shows that Zeynep did not receive formal technology education, that her knowledge of the technology discipline was formed through her own efforts, and that she did not include the standards of the technology discipline in her lessons. Zeynep also used technology for the same purposes as the other participants during the research (such as developing lesson plans, collaborating with colleagues, reflecting on her own learning, and mirroring images in her lessons). However, unlike the other participants, Zeynep made an attempt to use technology for conceptual learning, and it is observed that she did not improve her use of technology in her subsequent lessons since her attempt was affected by adverse environmental conditions.

According to the data analysis of Zeynep's lesson plans and the observation of lessons, Zeynep used technology in her integrated STEM lesson in three ways: first, she developed her lesson plans, using Word, or Web browsers, etc. second, she used technology to communicate and collaborate with her colleagues; this practice was created and supported by the researcher as a part of this research, and third, she used technology during her lessons for her students to build knowledge such as viewing images and seeing a video.

In the first module, Zeynep utilized technology for making her students see images to understand the context of the word problem. Students were shown images of wedding ceremonies, in particular, henna nights. Students discussed their former experiences about cultural heritages by analyzing the images. Then, Zeynep made students pose a mathematical problem by redirecting their attentions from what students noticed. Therefore, Zeynep used technology for her students to identify a mathematics problem.

Furthermore, Zeynep used Google maps to present satellite images of the two countries and their locations with respect to each other. She started to show the location of Istanbul in the google maps by zooming out. Zeynep showed all the neighbors of Turkey to students. However, this activity was interrupted due to the slow internet connection in the school. Then she used the satellite images of Turkey, Istanbul and the neighborhood where students lived. Unlike the other participants, Zeynep attempted to use technology for her students' conceptual learning. However, due to the negative environmental conditions, this attempt

was not as productive as she wished, and she did not attempt to use it in her subsequent lessons.

On the other hand, the teachers were asked to use Dropbox and google drive to collaborate with each other. As a part of this study, Zeynep uploaded the data including video recordings, audio recordings and documents. She utilized the sources that the researcher shared with them as well. Therefore, Zeynep used technology to collaborate with her colleagues. Also, Zeynep used technology to create her lesson plans and assessment tools. She used the online sources which the researcher supplied; moreover, she used Word to create her lesson plans and assessment tools such as formative assessment notebook, as well as the study worksheet and rubrics. However, it is analyzed that, Zeynep did not use technology standards in her lesson plans and in her lessons. This finding is in parallel with the other participating teachers' knowledge of the integration of technology. As Merve and Naz also stated, Zeynep did not receive a formal education in technology or educational technology topics. Her knowledge about technology integration is, therefore, limited.

4.1.3.2.8. Professional Growth

Teachers' knowledge of developing content knowledge and how they communicate about developing areas with their colleagues, how they cooperate and how they improve their skills are analyzed in this section (Corlu, 2014; Thiessen, 2000). According to the analysis of the data, professional development course seems to enable Zeynep to develop her pedagogical content knowledge and her own 21st century skills such as collaboration and communication. The areas that show improvement in her STEM pedagogical content knowledge are as follows; knowledge of teaching strategies, knowledge of assessment, knowledge of 21st century skills, and knowledge of context. The interviews made with Zeynep revealed that the teaching methods applied within the scope of this research were effective and contributed to permanent learning in Zeynep, that teachers' working together contributed to their professional development, and that the vocational development course held at the school where the teachers worked made it possible for them to attend for a long time without any teachers missing. Zeynep also stated that the resources provided to them during the research guided her in the process of developing STEM modules.

The structure of the professional development course was based on both employing collaborative approaches in which the researcher worked together with teachers in examining and analyzing their practices and rediscovering their beliefs and the impacts of those facilitating to build teachers' practices. Another important characteristic feature of the current professional development course was to hold this course at school where teachers practiced, stated by Zeynep as convenient. Zeynep argued that researcher's professional development course enabled them to learn from her colleagues. This course also motivated Zeynep to implement better practices. Moreover, Zeynep emphasized that practice-based professional development helped them to build practical and permanent knowledge. Zeynep stated her thought as:

For example, in this study, I can see my own shortcomings, and well, I can learn a lot from my friends with whom I work in the group. There is no age to learn. And I think everyone should learn something from each other. Also, it's very nice to see what we've learned, that is, by experiencing and practicing. Well, this is a very important thing. And you can learn it only in this way, you know, only in this way, permanent learning can be provided.

Additionally, she emphasized that she utilized the sources that were used in the professional development course to create her own assessment tools. Zeynep had the opportunity during this research to experience teaching methods that reflected the constructivist approach that she had not experienced in her previous teachings. In addition, Zeynep developed and implemented strategies that would appeal to students at different cognitive levels during this research. Zeynep stated that she was able to implement student-based teaching methods in her lessons inspired by the methods that were implemented during the professional development course.

During the research, Zeynep also had the opportunity to develop her context knowledge and aimed to plan lessons by considering the socio-economic conditions of the students and the cultures of the students. In addition, Zeynep had the chance to develop and apply her knowledge of the formative assessment approach during the research. After the studies on STEM education in the professional development course, Zeynep stated that she believed it would be beneficial to use a formative assessment tool as a better way of observing students'

learning. And she applied to the formative assessment tools she herself had developed in order to measure students' learning in STEM modules.

Zeynep, with this research, used technology to communicate and collaborate with her colleagues. She stated that it contributed to her self-evaluation of collaborating with her colleagues both in the development of the lesson plans, in the application process and in the reflection processes after the application, and her self-efficacy for performing STEM education. She stated that it was very convenient to benefit from technology in this process. Also, according to analysis of the data, Zeynep adapted collaboration and problem-solving skills in her STEM modules. Zeynep developed and implemented instructional strategies for her students to work collaboratively. She also worked on improving her problem-solving skills in all her lesson plans.

Finally, Zeynep stated that the design of the professional development course for the teachers in her school and the fact that it aimed to improve both their theoretical knowledge and practice, led to an increase in her motivation to develop and apply STEM education. Zeynep developed and implemented many skills that would contribute to her professional development (designing an integrated STEM module, developing, and applying tools to closely monitor student learning in line with achievements, using student-centered teaching strategies, working collaboratively with colleagues, utilizing technology during collaboration, etc.)

4.1.3.2.9. Knowledge of 21st Century Skills

Teachers' knowledge of 21st century skills, including (1) life and career skills, (2) learning and innovation skills such as critical thinking, communication, collaboration, problem solving and creativity and (3) information, media and technology skills are analyzed in this section (Tan et al., 2015). Zeynep's knowledge of 21st century skills were evaluated with the help of interviews, lesson plans, video record of lessons and teachers' reflective journals.

According to the analysis of the data, Zeynep adapted collaboration and problem-solving skills in her STEM modules. Although Zeynep did not include the learning outcomes of these skills in her lesson plans, it is seen that she focused on these skills in her lessons. It

is observed that Zeynep resorted to traditional methods many times in the development of problem-solving skills, but she did not include collaboration in her later courses because her students' readiness was not sufficient. In addition, although Zeynep stated that life and career skills were important, she did not include these skills in her practices.

Zeynep stated during our initial interviews that collaborative learning positively affected students' achievement. Additionally, she stated that collaborative learning was linked with students' positive intergroup relations, their ability to manage conflicts. She made an emphasis on her positive collaborative learning experiences during her college education and professional development trainings. What's more, she indicated students should be equipped to manage, define, understand, and solve problems that they encountered. She stated that students must take on an active role as problem solvers. Accordingly, Zeynep stressed collaborative learning and problem solving in her modules. Zeynep mentioned some sources of difficulties during the process of implementing collaborative learning. For example, students experienced difficulty with the focusing on task during the given time and they could not explain their work to each other and failed to be critical of others' work.

On the other hand, Zeynep stated in her reflective journal that her students developed their problem-solving skills during her implementation. She indicated that students learned:

1- how to solve a problem in different ways

2- to pose and define a problem

3- to identify what was requested in the problem and what information was given related to the solution of the problems.

However, we see that Zeynep uses traditional methods while teaching problem solving skills, and we also see that this is related to her knowledge of teaching strategies as well. Zeynep stressed the importance of teaching students' life and career skills her in-class practices did not reflect that she included these skills. There was an example of the fact that Zeynep included the life and career skills in her lesson plans. In the second module, Zeynep stated that engineers were needed to help her students on deciding how many trees they

needed to plant while they built the bridge. Data indicated that Zeynep's use of the role of engineer was superficial and limited in this module.

To summarize, Zeynep focused on developing collaborative learning and problem-solving skills. However, during the implementation, she redesigned her lessons and excluded the implementation of collaborative learning due to the fact that her observation about her students was not engaged with the objectives of the lessons. However, Zeynep showed limited knowledge of 21st century skills while teaching integrated STEM modules.

4.2. CROSS CASE ANALYSIS

To find the similarities and differences between the cases, each case was compared with the other and it was investigated whether the participants shared some common features. The answers to the research questions were answered in a way that analyzes the characteristics of all participants.

4.2.1. The Nature and Development of Teachers' Pedagogical Beliefs (PB) about STEM Education During Professional Development Program

Findings about the pedagogical beliefs of teachers about STEM education have been reported under three different headings. These are: (1) teachers' beliefs about the nature of learning and teaching, (2) teachers' beliefs about the nature of STEM disciplines, and (3) teachers' beliefs about context.

4.2.1.1. *Teachers' beliefs about the nature of learning and teaching*

The common features in each case were also analyzed and some patterns were found although teachers' beliefs about the nature of learning and teaching differ between cases. The first pattern is the observation that all teachers are inconsistent in their beliefs about the nature of learning and teaching. Long and detailed interviews and professional development meetings with teachers have demonstrated that teachers have conflicting beliefs. Every teacher has both traditional and non-traditional views on learning and teaching. For example, considering the traditional beliefs of Merve, her belief that "mathematical intelligence is

innate and cannot be changed" is observable. For the reason behind this belief, it is understood that Merve was exposed to traditional mathematics teaching throughout her teaching life. She did not succeed, and she could not feel successful in mathematics. Besides, she tried very hard but failed, and as a result of this, she believes that that she will not be able to change it no matter how much she works. Merve's traditional beliefs were also revealed while she was describing her views on teaching. For instance, Merve stated that she usually uses written exams or multiple-choice tests to evaluate her students' learning in mathematics. She also reported that unless students find the right answer and do not solve the problem by following her path, she does not give them full marks. Contrary to this, Merve has non-traditional, constructivist views on the nature of learning and teaching. For example, Merve emphasized that for effective learning, it is essential for teachers to start the lesson with a topic that attracts students' attention, with which students can establish a bond, and to apply methods that will enable students to discover for themselves in the teaching process. Regarding Naz's data, she had conflicting beliefs in the same way. To exemplify, Naz's belief about the social constructivist approach to education by indicating that students' effective learning takes place during group work. Similarly, during professional development meetings she remarked that children are born with a natural need to discover. She discovered it through her own observations, and that children reflected this in ways we didn't expect and were not accustomed to. Once again, based on her non-traditional views, Naz emphasized the students' inner motivations, and she believes that it is substantial for a student to devote time to a discipline with individual initiatives and to study hard to find his own solution to the problem. Naz's statements about her own teaching present her traditional beliefs. Naz explained that during her mathematics and science teaching, she asked students a problem and expected them to solve it. Then she chose one of the students and wanted him/her to solve the problem. Obviously, Naz's practices in mathematics and science teaching reflect her traditional beliefs. Examining Zeynep's beliefs about the nature of learning and teaching, it is striking that she has conflicting beliefs. For instance, Zeynep agreed with Merve during the professional development and stated that students' mathematical intelligence is innate and cannot be changed. With the in-depth interviews it is clear that Zeynep's belief was based on her own learning experience. Despite not being able to get support from her family throughout her education life and being educated in a low socio-economic region, Zeynep has always been successful in mathematics and science

lessons. She attributes this success to her innate intelligence. Interestingly, although Zeynep and Merve's learning experiences in mathematics and science classes are opposite to each other, the inference they both make is that they attribute success or failure to innate genetic characteristics, intelligence. By induction, both linked their experiences to intelligence, which they believe has an unchangeable structure and which they believe they bring from birth. Zeynep's another traditional belief is that quick problem solving in mathematics is a sign of success. It is clear that Zeynep made statements about this belief based on her experiences in her traditional education life. Conversely, Zeynep also has contradictory beliefs. Elaborating Zeynep's non-traditional beliefs, it is seen that she thinks that the students are born with a tendency to discover. Zeynep argued with the idea that when students learn by having fun, the information they learn is more permanent. She also stated that she believed that learning should be related to real life. She remarked that she thought that memorization should not have a place in learning and that for learning to take place, learning by comprehension and questioning should be provided. On one hand, Zeynep defines teachers as the people who convey information, on the other hand, she expresses the need for students to solve the given mathematics and science problems in the way they are taught and reveals her conflicting beliefs about the nature of learning and teaching.

The second pattern is that all teachers separate their beliefs about the nature of learning and teaching in traditional learning and STEM education. This means that the analysis of the beliefs of teachers about learning and teaching in STEM education shows that according to all teachers, learning and teaching were different and new in this model. They underlined the necessity of learning and teaching with a constructivist approach in STEM education. Although there is an emphasis on the constructivist learning model in STEM education by all the teachers, all participants underscored different aspects of student and teacher roles. For example, Merve believes that there is an opportunity to develop higher order thinking skills of students in STEM learning. She also thinks that the information learned is in the context of real life and is applicable for students. She points out that students can establish relationships between disciplines. She also stated her opinion on the changing role of the teacher in STEM education and talked about the need for the teacher to do more preparation in STEM education, and to increase the content knowledge in order to answer students' questions. According to Merve it is necessary for teachers to step out of the character of the

person who conveys the information and to guide the students with the right questions and to enable the students to discover for themselves. Whereas Naz remarked that STEM education is suitable for the theory of multiple intelligences, that different intelligence areas of the student can be addressed with STEM education, and that students should be active in this education process. According to Naz students can succeed in STEM education even without a teacher. Besides, Naz emphasized teachers' changing role in STEM education she stated that the teacher should guide the students by asking questions and not by giving information. Nevertheless, Naz stated her belief about the difficulty of measuring students' learning in STEM education. Similarly, Zeynep stated her beliefs about the changing roles of teachers and students in STEM education. She emphasized that in STEM education, the teacher should be in the position of observer and guide. She said that she should provide an environment that will enable the student to explore. She believes the way to do this is through group work and product design. In addition, Zeynep felt that since STEM education is not included in the curriculum, with the individual initiative of the teacher, it will enable students to learn by having fun without the stress of written exams. In particular, she thinks that problem posing and solving skills and the collaborative working model are indispensable in STEM education. In this way, it is different from traditional education. Moreover, referring to her opinion, she states that student-centered teaching models to be applied in STEM education would lead teacher roles to change. And, she would have difficulties especially in classroom management.

4.2.1.2. *Findings on teachers' beliefs about the nature of STEM disciplines*

Analyzing the teachers' beliefs about the nature of STEM disciplines, the data are grouped under 4 subtitles including (i) teachers' feelings about STEM disciplines, (ii) their experiences with these disciplines, (iii) their views on the place of these disciplines in integrated STEM education, and (iv) finally their beliefs about the nature of each of the STEM disciplines. On the findings of the research, it is seen that five important patterns come to the fore. The first of these is that all of the teachers are exposed to traditional learning throughout their education life, the second is that teachers divide mathematics and science disciplines into two as mathematics in school and mathematics in nature after the professional development course. The third one is teachers' misconceptions about the teaching of technology and engineering disciplines and their lack of self-efficacy beliefs.

The fourth is the similarity in the definitions of the teachers for STEM education and the similarity in the sources of their beliefs.

To explain the first pattern, all teachers have been exposed to traditional teaching in the fields of mathematics and science throughout their education life, at all stages from primary school to university education. However, teachers' feelings about this education vary in parallel with whether they are successful in these courses or not. For instance, Merve and Naz said that they always felt unsuccessful in mathematics and science lessons at school. They could not succeed in these lessons no matter how hard they tried, and they had negative feelings about these disciplines. While Zeynep remarked that she was always successful in mathematics and science lessons at school and that never biased towards these lessons and her success in each education level was instrumental in her success in the next education level. Another important point of interest here is that although Merve and Naz generally have negative feelings about mathematics and science disciplines and evaluate their learning negatively, they only remember the times that they experienced student-centered teaching in these disciplines (group work, learning by experiment, living by doing, learning, etc.). And they associate these moments with positive emotions.

Secondly, all teachers consider mathematics and science disciplines as factual knowledge before study. However, after participating in the development course, they started to relate science and mathematics in with real life contexts, and they emphasized the conceptual understanding. It has been observed that the professional development course worked well in changing teachers' beliefs. Nonetheless, it is difficult to say teachers' beliefs have changed completely. In the interviews, it was seen that teachers described mathematics and science as science and mathematics at school, and science and mathematics in real life, and examining the impact of their beliefs in their teaching. It was seen that the old beliefs more dominantly influenced their classroom practices, and their new beliefs were put into context. To put it more clearly, teachers' view of science and mathematics teaching was based on rote learning, based on the explanation of information, with the science and mathematics discourse at school. With real-life science/mathematics teaching discourses, they started to describe learning based on the students' examination of the subjects in these courses in their real context and learning in-depth and conceptually. All teachers want to teach real-life-based in their classrooms. However according to them because of the various

reasons such as the time limitations the existing curriculum, the high stake test, it is impossible in Turkey. The data of the current study clearly indicated that teachers' contextual beliefs prevent the implementation of their beliefs about disciplines.

Third, the findings of the study exhibit that the teachers have some misconceptions about the engineering and technology disciplines, which have an important place in integrated STEM education. With respect to the believes of teacher, they have low self-efficacy beliefs in the teaching of these disciplines. The teachers participating in this study said that they did not take a course on technology and engineering disciplines or about the teaching of these disciplines during their university education. Still, there is no technology education course in the school curricula for the students, and the knowledge that teachers need to know about these disciplines in order to work in these schools does not go beyond basic computer usage skills. All the knowledge of the teachers about these disciplines comes from a 4-day professional development course they attended on their own initiative before this research.

It is noteworthy that all the teachers have low content knowledge about technology discipline and about how to teach it, and as a result, low self-efficiency. When asked about their views on this discipline, all teachers consistently stated that they did not know what the scope of the technology discipline, its role in STEM education, and the teaching about the technology discipline were. While Naz expressed this as: "*When you say technology, it's as if electricity must be involved, right? So, this is a big question mark for us as well. I don't know, but what's the scope of technology?* Merve remarked: "*Technology is a dead end for us.*" In contrary, in-depth interviews with teachers demonstrated that they developed conceptual misconceptions about the technology discipline in the professional development course they had attended before. The teachers developed a new belief during this course. According to this, it was sufficient for the students to produce prototypes with waste materials and to acquire analysis skills. Some activities such as examining good examples for the use of technology in education, experiencing the use of accessible technological tools (google maps, google cardboard, etc.) are carried out to facilitate learning about technology integration. However, data analysis demonstrated that teachers do not use these tools in their practices. When they attempt to use them, the infrastructure does not allow this. The observations of the study indicated that the teachers did not straighten their misconceptions.

Additionally, they could not include the learning outcomes of technology in their lesson plans and lessons. Teachers' misconceptions about the integrate technology discipline seems to be the result of their previous incomplete learning and the facilities of the school they work in. In a similar way, teachers' misconceptions, and the lack of self-efficacy beliefs about engineering discipline has been revealed. It was observed that all the teachers associated the engineering discipline with designing concrete materials and the engineering design cycle. The results showed that their beliefs come from their previous learning in the professional development course they participated in.

Fourthly, the teachers had an understanding that engineering, science and designing a material were at the center, that the discipline of mathematics was only involved with some learning outcomes (symmetry, measurement). In the process of the professional development, teachers were introduced about different pedagogical approaches applied in STEM education and provided with some applications, and the videos of the good practices were discussed by watching the videos. After this course, it is observed that teachers started to use different teaching methods such as mathematical modeling, problem-based learning, that they can include different learning outcomes in mathematics and science disciplines in their integrated STEM education plans. Moreover, they seem to adopt an integrated STEM education approach in which the student learns by questioning and discussing. Concordantly, it has been concluded that teachers' conceptual understanding of integrated STEM education has changed and improved.

The fifth finding is that the most important factor in examining the sources of teachers' beliefs is their own learning experiences. Furthermore, it has been observed that the experiences they had during their student life and during the years they worked as teachers equally impacted their beliefs. Teachers usually explained their opinions by giving examples from their experiences. Interestingly, teachers frequently remember their positive experiences in more detail, and they superficially remember negative experiences. When teachers have conflicting experiences with each other, context has been found to be effective in transforming these beliefs into practice. For example, it is seen that when Merve obtained conflicting information about the technology discipline in integrated STEM education in two different professional development courses she attended. Yet, she chose the one that reflects on her classroom practices that is aligned with her school's capacity. In one respect, this

finding also leads to an important conclusion. Teachers can adopt new beliefs with new experiences throughout their professional lives which can be promising finding for teacher education research.

4.2.1.3. *Findings on Teachers' Contextual Beliefs*

The data of the current study showed that there are three important findings. First of all, the professional development of public-school teachers is not valued enough. Secondly, the inadequacy of physical conditions at school negatively impacts teachers' use of innovative methods. The third is about difficulties arising from the social background of the region where the teachers work, one of which is lack of parent involvement.

All the teachers agree that the education they are involved in during their university education is not sufficient to apply the new educational pedagogies that exist in the changing and developing education system. At the same time, they emphasized the importance of developing content knowledge as well as pedagogical content knowledge for effectively transferring current and quality content to students. Moreover, according to teachers' professional development courses are necessary in this development process. However, another important issue emphasized by the teachers is that the professional development of public-school teachers is not given enough importance in Turkey. The teachers stated that they came to this conclusion based on their own experiences. The teachers highlighted their beliefs about the ineffectiveness of the professional development courses provided for public school teachers and the fact that attending these courses had no effect on the careers of the teachers demotivate them. Additively, they encounter various difficulties when they want to attend quality and effective professional development courses individually. For instance, teachers' curricula are not adjusted, they must cover course fees and travel expenses, and they do not have a positive effect on their careers.

All the teachers believe that the overloaded curriculum and the time lag between the curriculum and implementation has negative effects on students' learning. The teachers indicated that due to these obligations, the teachers had to move on to the next topic before the students could comprehend the topics sufficiently. They also expressed that they believed it is difficult to use innovative methods (such as integrated STEM education, project-based teaching, problem-based teaching, etc.) because the role of high-stake tests in the education

system. These tests put pressure on the subject that teachers would focus on. One reason for this situation is that there is a necessity to teach the learning outcomes given in a certain period. The other reason is that the parents force the teachers to convey the information that will enable the students to be successful in the exam only as soon as possible.

Another contextual belief shared by teachers is that poor conditions of the school environment have negative effects on learning. Poor conditions prevent teachers from applying effective pedagogical approaches. Particularly, they cannot improve themselves in the field of technology and use them effectively in their lessons. Thus, they believe that both the difficulties they experienced before this research and the difficulties they experienced during this research hindered their effective STEM instructions. In fact, this belief has led some teachers to never apply to the existing effective technological pedagogical content knowledge.

The data of the current study showed that teachers beliefs that they would have difficulties for parent involvement to the STEM implementations. Their beliefs stem from their previous experiences with parents. Teachers stated their willingness for students to learn actively at home. They create homework where students may continue to learn. In these cases, parents either do not support the student or do the homework for the student. For example, concerning the inquiry-based learning model, Merve gave an assignment. In this homework, students were expected to visit a bakery with their families, to ask questions and to examine the subject in depth. She reported that instead of talking and discussing together and letting the children find their answers, the parents answered it themselves. Moreover, the parents do not support innovative educational practices. Teachers who teach with direct instruction method and lecture-based teaching is evaluated as more effective teacher and this negatively influences the motivation of the teachers. For instance, Naz expressed that when she needed materialism order to be able to implement effective teaching in the classroom, the parents questioned the teacher's methods instead of supplying these materials and said that these methods were unnecessary. Similarly, Zeynep stated that during the project-based teaching practices, families did the assignments instead of the children.

The teachers' contextual beliefs towards parents might also have an impact on the STEM education as all of the teachers have been working in this school for a long time. Analysis

of teachers' lesson plans and documents showed that only in-class learning was included, and out-of-class learning was excluded. Teachers have created their lesson plans to not require family support. Moreover, although the teachers knew that some concrete materials would be needed for effective STEM education and that they did not have access to these materials at school, they did not receive support from the parents, instead they used the recyclable materials obtained by their own means. Thus, teachers' contextual beliefs have influenced how teachers' pedagogical content knowledge appeared in classroom practices.

4.2.1.4. *The Teachers' Changing Beliefs During the Professional Development*

It was seen that there was a change in teachers' beliefs about the nature of disciplines, which would contribute positively to effective learning. Conversely, it was concluded that the teachers' beliefs interacted with the professional development, produced different results, and the reason for this was the difference in each teacher's previous learning and previous beliefs.

First, regarding the teachers' beliefs about the nature of disciplines, Merve started to associate the discipline of mathematics, which she previously saw as the transfer of facts and thought that lecture-based methods would provide effective learning, with problem solving and real life. In contrast, Zeynep also conceptualized mathematics discipline as consisting of operations and numbers beforehand; however, at the end of the research she emphasized the relationship between mathematics and real life. In addition to this, Zeynep defined the science, which she described with rules and formulas before the research, as accessing information through questioning and observations. Besides, all the teachers work in a way that relates the learning outcomes to the real lives of the students during the STEM applications. This implies that teachers' beliefs about the nature of science and mathematics disciplines have changed during this research.

Furthermore, before the study, teachers were unable to articulate the role of mathematics in their conceptions of STEM education beyond the use of symmetry and operations to calculate their designs. During the study, it was observed that teachers also used different teaching methods (i.e., mathematical modeling, problem-based approach, etc.) in their STEM lessons during the study. The data analysis revealed that lesson plans included the mathematics standards. This demonstrates that the teachers were able to consider the

integrated STEM education in a more inclusive way and they placed more emphasis on the relationship between disciplines.

In addition to these, results of the study indicated that there are considerable changes in the beliefs of teachers on the nature of teaching and learning. In the last interviews teachers declared that it is important for students to learn by discovery and stated that they believe it is important for students to structure their knowledge themselves. Two things are thought to have had an impact on this change; first, the professional development was designed by taking the principles of the constructivist approach into account and second, the content was designed to put student learning at the forefront. For example, the teaching methods and techniques applied during professional development were designed to encourage teachers' collaborative work, and the teachers were provided with an environment to work together during the professional development, and with an opportunity to develop new information by associating it with their previous knowledge. In addition, teachers watched good example videos and discussed possible implementation of the methods in their classes. Also, teachers designed lesson plans together to implement methods that support inquiry. Analysis of the in-class practices of the teachers showed that they used the teaching methods and techniques which were applied during the PD in their own lessons. It can be said that those teachers are inclined to use the methods they have experienced in PD in their classrooms. Besides teachers indicated that constructivist approach contributed them to learn together and from each other. Zeynep expressed this as follows: “With this study, I can see my shortcomings a lot, so I learned a lot from my friends with whom I worked with as a group.” Teachers stated that they understood the importance of focusing on student learning throughout the study. For instance, Naz expressed her changing beliefs as: “We were always focused on what we were doing, but what did the kids learn? What happened to learning? I realized that I need to pay attention to this in this study” and mentioned that she could see that students learn better by using student-centered teaching methods and formative assessment tools.

Finally, teachers stated that they became aware of the influences of their own beliefs throughout the study as teachers wrote reflective diaries about their practices. While writing reflective diaries, teachers had the opportunity to look back at their practices and make self-assessments concerning them. The teachers watch and analyze their own practice videos. They had the possibility for analyzing the theoretical and practical information on effective

STEM education, and then to evaluate their own practices with the rubrics provided by the researcher. Teachers have pointed out that their contextual belief is particularly effective in their students' learning, and even if they cannot change the context they are in, they believe that changing their belief is important for student outcomes.

4.2.2. The Nature and Development of Teachers' Pedagogical Content Knowledge about STEM Education During Professional Development Program

A systematical examination of teacher's experiences and knowledge is carried out to understand teachers' pedagogical content knowledge (PCK). Examining teachers' cases allowed us to understand the tendencies in their experiences. In the light of the relevant literature the analyzes of the data were blended and the teachers STEM PCK were examined under 4 subtitles. These are: 1. Knowledge for teaching, 2. Knowledge of context, 3. Teachers' developmental knowledge, 4. Knowledge of integration.

With the findings of the study, four headings are presented under the title of Knowledge for Teaching. These are knowledge of teaching strategies, knowledge of curriculum, knowledge of assessment, knowledge of students. These categories were created with common themes obtained from interviews with teachers, audio recordings, video recordings of teachers' classroom practices, and data obtained from teachers' lesson plans and reflective diaries. In the lesson plans, the teachers were expected to mention their rationale. Teachers are expected to explain followings aspects in the reflection papers: important skills, learning outcomes, learning strategies, process, teaching strategies, their views on learning difficulties, materials, educational technologies, and resources. In addition, they are asked about the positive and negative points they see in the lesson process. They also report the new awareness that the teachers have developed, the views on the students' learning, the things they want to change about this lesson, and the features they want to improve about the next lesson. The classroom practices were analyzed with both observation and video recordings.

4.2.2.1. ***Elementary School Teachers' Developing PCK***

As part of this research, teachers' teaching strategies, curriculum knowledge, student knowledge and knowledge of assessment were categorized under the title of Knowledge for Teaching.

4.2.2.1.1. Elementary School Teachers' Teaching Strategies

The data of the current study showed that before the implementation of the professional development program teachers have limited conceptions about STEM education. The teachers think that engineering and science disciplines are fundamental. In their beliefs, mathematics is included with limited subject areas and technology is not included. In the progress of the program, it was observed that teachers gradually developed important conceptions. The results suggested that teachers developed comprehensive views about STEM education. Teachers stated the importance of inclusiveness, connections between all four disciplines and in-depth learning. The teachers are observed to include the learning outcomes in the mathematics lesson plans and make an effort to implement the necessary teaching strategies for students to learn more effectively.

The findings indicated that teachers' integrated STEM lessons are generally misapplication lessons. The concept of "misapplication lesson" means teachers' description of the lessons that are actually product design or the use of concrete materials as engineering design or mathematical modeling. For example, in one of the STEM modules, Merve asked the students to design a building with 20 rooms and 5 floors. Regarding the design of this building, each floor should have a different cultural value. In another module, she asked her students first to draw a prototype on paper with the recyclable materials, and then design a toy. Similarly, in the first module, Naz made her students to design the backyard of the school as a hobby garden. In the second module, she planned a lesson for her students to design a recycling material using waste materials. In the third module, she asked her students to design an artificial environment with recyclable materials. In comparison with this, Zeynep designed a lesson in the first module that requires her students to solve a mathematical problem with more than one method. The problem that Zeynep posed is as follows; "The engineers who will build the bridge have a problem. The length of the bridge

is 40 meters. They will plant trees 5 meters apart on both sides of the bridge. They cannot find out how many trees they need for this. They want us to help them." Zeynep has associated this question with other disciplines. Therefore, she thought that it is an integrated STEM lesson, but, in fact, it is a type of "mathematical word problems". In the second module, the following question, which is another word problem, was the core activity: "Ayşe's sister will have a wedding soon. As you know, henna nights are organized before weddings. A henna night will be held for Ayşe's older sister. 20 guests were invited to the henna night. 10 tables were prepared for the guests. How do you think the guests should be placed at these tables?" In our interview about this lesson plan, she mentioned word problems as mathematical modeling.

Current studies stress that the engineering course should include clear and explicit engineering learning objectives. Engineering design is one of the most basic principles of engineering activities (Guzey et al., 2014). Also, the engineering design process should include (a) problem and background, (b) plan and implement, (c) test and evaluate (Moore et al., 2014). The lesson plans and the interviews with teachers showed that although they described the activities in STEM modules as engineering design, they actually used the word design literally. Similar issue can be seen in mathematics. Mathematical modeling is defined as a process of producing sharable, modifiable, and reusable conceptual tools for describing, predicting, and controlling real life situations (Lesh & Doerr, 2003). To be able to express a real- life situation in mathematical language effectively, students must have higher-level mathematical abilities beyond just computational and arithmetical skills. These skills might include spatial reasoning, interpretation, and estimation (Lehrer & Schauble, 2003). Analysis of the data indicated that by modeling, teachers meant the use of their students' concrete educational tools (mathematical manipulative) in solving word problems. The student outcomes reached by mathematical modeling could not be achieved. In conclusion, it is seen that all the teachers' plans are misapplication lessons. They are either misapplication mathematical modeling or misapplication engineering designs. By misapplication mathematical modeling we mean teachers use the word modeling and students' visual drawings of their solutions instead of mathematical modeling. By misapplication engineering design category, we mean teachers' use of hands-on material design activities

instead of the engineering design concept. The reason behind the misapplication lessons might be the teachers' lack of content knowledge in these areas.

Subject-specific and topic-specific strategies were determined based on the analysis of the teachers' lesson plans, lesson videos, interviews, and teachers' reflective diaries. Merve uses more student centered subject specific strategies. Naz and Zeynep seem to use mostly teacher-centered strategies. However, the case of Naz and Zeynep also differs within themselves. Naz never tried to use student-centered methods, but Zeynep initially applied it and later switched to using teacher-centered methods.

The subject specific strategies used by Merve indicate that they are all student-centered and used to improve active learning and classroom management. Interviews with Merve have demonstrated that most of the methods are the strategies used by the researcher during professional development. For example, strategies such as 3 act tasks, notice/wonder, creative brainstorming with post-its are the strategies we have practiced during the professional development. Regarding the analysis of Naz's strategies, it is observed that she mostly uses hands-on activities. She also uses lecturing, storytelling, and question-answer methods. In addition, she implements student-centered methods such as station rotation model, gallery walk, classifying concepts with post-its. However, it is seen that Naz uses hands-on activities in most of her lessons because of her misunderstanding and application of engineering design. Furthermore, the way Naz uses the methods reflects Naz's beliefs about the students. Naz summarized the subject to her students using the lecturing method at the end of all the lessons. Naz explains the subject because she believes that it is for the benefit of her students. Therefore, it is clear that Naz's practices reflect her belief. Besides, she reported that the student-centered methods she used for the first time in this study made classroom management difficult. According to her, having a large number of students reduced the effectiveness of these methods and thus, she needed to develop herself more in applying these methods. Zeynep included the student-centered strategies, such as group work and think-pair-share, inhered lesson plans. However, Zeynep changed her plan and switched to the question-answer method. As there emerged the problems related to the classroom management. This is because Zeynep's students could not speak by following the rules during the application. In another STEM lesson, Zeynep initially designed as collaborative problem-based STEM module, however she has made changes due to the lack

of her students' level of readiness. During the lesson, Zeynep first made individual problem-solving then made the students study individually on the worksheet. Concerning Zeynep's practices, she generally applies teacher-centered methods. As mentioned by Zeynep, the reason for this change was the inadequacy of the readiness of the students and the large class size was designated.

Analysis of topic specific strategies revealed that Merve and Naz had limited use of topic-specific strategies. Whereas Zeynep had an advanced topic-specific strategy knowledge regarding the discipline of mathematics. Merve used only two representations in her lectures. These are arrays and number lines. She has benefited from these representations in the same course. She used these representations while explaining the methods used by her students to the whole class after the study in which her students performed a division operation. It was observed that Naz used length models to show her students alternative methods to word problem in one lesson. Zeynep used more than one topic specific strategy in her classes. Particularly, in the first module, the notice/wonder activity is used to solve the word problem. In the second module, during the solution of division, multiple methods, and representations such as skip counting, direct modeling, and number line are used. However, all the topic-specific strategies she uses are within the discipline of mathematics. A detailed examination of the topic strategies indicates that they are very limited and all within the scope of the discipline of mathematics. Also, they are generally limited to representations.

4.2.2.1.2. Elementary School Teachers' Knowledge of Curriculum

It has been found out that all of the teachers are competent in general curriculum knowledge. They determine the learning outcomes of mathematics and science in parallel with the curriculum in their lesson plans. Additionally, they have difficulty in finding resources for the engineering and technology standards.

The data of current study indicated that teachers had difficulty in determining the learning outcomes of the technology and engineering in their planning. The first reason for this difficulty is the absence of a written curriculum for these disciplines. The curriculum should be accessible to teachers and defined by the Ministry of National Education. Also, it

should be prepared at the level of the class. Second, teachers need environments to practice these disciplines in order for these courses to be included in the lesson plans. The teachers remarked that they excluded the learning outcomes while preparing their lesson plans because of their insufficient access to technology at their schools. Third, the teachers determined the learning outcomes by considering the time lag in the curriculum. According to the teachers' interviews, it is a part of their job description and a priority for teachers to address curriculum over a period of time. Therefore, they have chosen the learning outcomes of mathematics and science / life science courses in parallel with the curriculum. On the other hand, Naz did not associate the planned activities with the standards. The activities she implanted were hands-on activities rather than integrated STEM lessons. Naz used hands-on activities to engage her students to the craft activities. Therefore, these activities did not contribute significantly to students' conceptual learning, although they designed a product while doing these activities.

4.2.2.1.3. Elementary School Teachers' Knowledge of Student

It has been concluded that the teachers plan their lessons by considering the contexts of the students. Additionally, they know the interests of their students and they associate them with the learning outcomes. Nonetheless, teachers mostly do not teach by addressing students' learning difficulties or misconceptions. This may be due to the inability to provide the necessary environment for the development of conceptual learning because they do not design lesson plans that provide in-depth learning. However, teachers used tools to monitor students' learning more closely and gained new information about them. Additively, it has been set forth that teachers' beliefs influence how teachers' knowledge of students is reflected in their classroom practices. These findings are discussed one by one in the next paragraphs.

Since all of the teachers knew their students, they designed their lessons by taking their interests into account. The teachers associated the subjects they are interested in with the lessons they plan to teach. They plan this particularly in the introductory part of the lesson, in order to draw their attention. The analysis of the data related to the teachers' lessons assert that Merve and Naz did not consider the previous learning of their students. Zeynep, contrarily, specified the goals and achievements by determining the previous learning of her

students. Similarly, while Zeynep designs activities that address the misconceptions that students encounter during their lessons, Naz and Merve seem to ignore them.

The teachers included the use of formative assessment tools in their lesson plans in order to observe student learning more closely. They mentioned that as a result of this, they discovered some information about their students that they had not realized before. Three important awareness stands out in the statements of the teachers. The first is the impact of students' reading comprehension skills on their success in STEM. The second is that students' verbal expression skills are better than their written expression skills. The third one is that the students who had low success in their classes before, showed high success during their STEM applications.

In addition to awareness mentioned above, there are two other remarkable findings. (a) First, Zeynep used culturally relevant pedagogy (CRP) unlike other teachers. (b) And Naz designed STEM lesson plans on the previous lessons' subjects. This means Naz did not used integrated STEM lessons to teach a new subject or to introduce a new concept. Her low self-efficacy beliefs and low content knowledge for STEM practice may be prevented her from actively using her knowledge of students.

4.2.2.1.4. Elementary School Teachers' Knowledge of Assessment

Based on the observations, Merve and Zeynep have improved their knowledge of assessment. They also developed their skills to use appropriate tools that would monitor student learning more deeply. On the other hand, Naz's knowledge of assessment is very lacking.

The results showed that the teachers had very little knowledge about the purpose of the assessment and assessment tools at the beginning of the study. However, they stated their willingness to learn and apply nontraditional assessment tools. Eventually, the teachers' understanding about using assessment evolved from "testing" to "monitoring student learning". Merve and Zeynep set measurement objectives that are consistent with the aims of mathematics and life studies courses. They mostly used a assessment tool that allows them to examine students' learning in depth. Naz, oppositely, was not found to be at a sufficient

level to improve learning and self-regulation in students. She could not set assessment goals that appealed to learning outcomes although she did practices for utilizing formative assessment tools. The reason for this is Naz did not planned activities related with the learning outcomes. It is also because she could not set learning criteria and learning goals for these activities.

The findings also revealed that all the teachers excluded the engineering and technology disciplines when designing the assessment tools. This is a finding parallel to the teachers' lack of content knowledge in these areas.

4.2.2.2. ***Elementary School Teachers' Knowledge of Integration***

In this section, the analysis is made under the title of Elementary School Teachers' Integrative Thinking. This title consists of the following subjects: teachers' ways of integrating disciplines into STEM lesson modules, which disciplines they focus on by including content in teaching, and patterns that stand out in the way they include disciplines in their lesson plans and classroom practices. Nonetheless, another theme that emerged during the research is the similarity in primary school teachers' knowledge and practices regarding technology integration in public schools. This theme will be reviewed under the heading of Elementary School Teachers' Integration of Technology.

4.2.2.2.1. Elementary School Teachers' Integrative Thinking

The data of the current study showed that, STEM integration forms of the teachers supported the context integration model. This model, as stated in Brian and colleagues' study (2015), refers to teaching a discipline within a story in another discipline. The content integration includes units and activities. These activities might include a few of the STEM disciplines during the teaching of the content of the discipline in the center (e.g., science) and the content of another discipline (e.g., mathematics) in a meaningful way.

Bryan and colleagues (2015) stated that a well-structured content integration is essential for effective STEM education. For students to learn the content related to STEM disciplines, it is necessary to emphasize the learning outcomes of each of these disciplines. Teachers

have included mathematics as a central discipline in their lesson plans. They have also benefited from the standards from other disciplines to reinforce the learning outcomes in the central discipline. Besides, in most of the lesson plans, teachers did not include the learning outcomes of technology and engineering discipline in their lesson plans. They only included the subject of designing a product related to the field of engineering.

4.2.2.2.2. Elementary School Teachers' Knowledge of Technology Integration

Data analysis showed that all teachers' content knowledge of technology and their knowledge of technology teaching are limited. All teachers lacked the learning outcomes of the technology discipline in their lesson plans. They remarked that they did not take a formal course related to the technology discipline and the teaching of technology during their university education. They also mentioned the absence of professional development courses in this field during their professional life. The teachers explained the reason for this in several ways. First of all, since the schools do not have the equipment to teach the discipline of technology, teachers think that they cannot use the knowledge they have acquired even if they improve themselves in this field. Another reason is teachers' having no legal responsibility because they do not have technology-related learning outcomes in their curriculum. And lastly, the professional development offered to teachers in this field is insufficient and teachers' access to these training is very limited.

Teachers benefited from technology in 3 ways although their knowledge of technology integration is restricted. Teachers often resorted to technology in the introductory part of the courses to show their students an image or a video to attract students' attention to the subject. Contrarily, teachers used applications such as Word, Excel, and web tools in the process of preparing lesson plans during this research. In addition, the teachers benefited from cloud technology during the professional development course. They stated that they would prepare their own projects and presentations by using the data here after the research.

4.2.2.3. ***Elementary School Teachers' Developmental Knowledge***

Teachers' development in meeting the needs of their students in STEM education and changing knowledge and developing understanding and ideas are analyzed under this

category. Their developing professional knowledge was presented in 2 sub-categories. These are: (1) Elementary School Teachers' Knowledge of 21st Century Skills and (2) Elementary School Teacher's Professional Growth.

4.2.2.3.1. Elementary School Teachers' Knowledge of 21st Century Skills

Analysis of the data indicated that the teachers gave importance to "collaboration" in their lessons and included it in their lesson plans. Merve and Naz reported the improvement of their students' collaboration skills. Inversely, Zeynep thought that her students could not learn the content and did not learn the learning outcomes sufficiently when she implemented collaboration-infused lessons. Thus, she did not apply cooperative learning in her next lessons. In addition, Merve had knowledge and practices addressing all 21st century skills. However, Naz only focuses on collaboration, life and career skills. Zeynep focuses on collaboration and problem-solving skills. Differently, there is something that Naz and Zeynep have in common in teaching 21st century skills. Naz teaches life and career skills and Zeynep teaches problem solving skills in traditional ways. For example, Naz teaches the role of landscape architecture and the fields of study with the method of explaining their roles. Zeynep teaches with a teacher-centered method by showing problem solving skills and getting them done.

Another prominent finding is that while teachers include 21st century skills in their practices, none of them include these skills in the lesson plan under the title of 21st century skills. Merve taught 21st century skills in terms of engineering skills. It has been seen that the learning outcomes that Merve added to her lesson plans as engineering are, in fact, 21st century skills. Naz and Zeynep, diversely, added the learning outcomes related to 21st century skills as social skills outcomes. Further, regarding teachers' knowledge of 21st century skills, teachers did not fully reflect their beliefs in classroom practices. For instance, Zeynep stated the importance of life and career skills, but she did not plan her lessons accordingly.

Finally, the data indicated that teachers do not aim to measure 21st century skills. None of them planned the assessment and evaluation processes related to 21st century skills. Nevertheless, according to the teachers, the communication skills and problem-solving skills

of their students improved in general. Besides, according to teachers their students' awareness of STEM careers increased.

4.2.2.3.2. Elementary School Teachers' Professional Growth

Teachers' developing professional knowledge and which learning conditions would best foster teachers' pedagogical content knowledge and beliefs in STEM education have been presented in this section. As teachers participated a professional development program and worked collaboratively and practiced with integrated STEM model. Therefore, it is predicted that there will be development in the elementary teachers' professional knowledge, beliefs, and classroom practices. All the teachers participated in all the processes of the research from the beginning to the end for 6 months and during the winter break. According to teachers, participation is more convenient, comfortable, and convenient since professional development is job embedded. Teachers are encouraged to work and reflect together during the study. The place of learning and practice is their school. These conditions make it possible to teacher participation in the study. Teachers applied the student-centered methods in their own lessons. In these courses, a professional development specialist is at school. He/she has positively affected the existing restrictive mindsets of teachers. This seems enabled them to design and try to implement innovative practices in a way that enhances students' learning despite the poor conditions of the physical environment in their schools. Moreover, all teachers expressed the effectiveness of the design of the professional development program as it addresses both theory and practice. The teachers stated that they were able developed their pedagogical content knowledge and beliefs since the course was designed considering their real context. During STEM education practices, they communicated with each other both during the lesson preparation, the application and afterwards in the reflection process for the lesson. They had the opportunity to think and reflect on their own teaching. All of the teachers worded that providing a supportive environment improved their teaching.

Additionally, analysis of the post-interviews showed that teachers made forward-looking plans for their own professional developments. Teachers planned to present the outcomes of their professional developments and practice workshops and prepare for a STEM lesson plan competition. They also plan to participate in new professional

development courses and in teacher workshops on platforms such as STEM supported by the European Union. The teachers who had the opportunity of professional development became more open to the idea of developing themselves professionally. To sum up, the teachers who had the opportunity of professional development became more open to the idea of developing themselves professionally.

Lasty, results of the study revealed that the reason for the limited development of teachers' knowledge and beliefs about STEM education may be the lack of content knowledge and low self-efficacy. For example, Naz stated her low self-efficacy beliefs throughout the study. She designed and implemented STEM instruction on the subjects she has taught her students before, because she didn't feel ready to use an integrated STEM model to teach a new concept. Besides, resources were provided by the researcher to improve Naz's STEM education experiences, but Naz stated that she did not use these resources because the content knowledge was very difficult for her. In short, Naz postponed acquiring new experiences about teaching. It seems that Naz's lack of content knowledge and her low self-efficacy beliefs have caused the development of her knowledge and beliefs about STEM education to be very limited. But exploring the relationship between the pedagogical content knowledge, content knowledge and self-efficacy beliefs of elementary teachers is beyond the scope of this research.

4.2.2.3.3. Elementary School Teachers' Knowledge of Context

Five factors emerged regarding teachers' knowledge of context. These are country, community, school, student, and teacher. Based on the observations, the conditions of teachers in the context of school and country have a negative impact on STEM education. In particular, the lack of adequate equipment in the school and insufficient family support and participation have revealed that it prevents teachers from carrying out comprehensive and qualified practices. In addition, compulsory curriculum, time lag, large class size are the other factors that negatively affect teachers to deliver quality integrated STEM education.

4.2.3. The Impact of the STEM-Focused Professional Development Program on Elementary Teachers' Cognitions and In-Class Practices Regarding STEM Education

Based on the findings of the study, the professional development program contributed to the teachers' development of pedagogical content knowledge and their beliefs from different perspectives. Therefore, the professional development program improved their classroom practices.

First of all, the results of the study indicated that the teachers' teaching methods and techniques have improved. The teachers experienced teaching methods and techniques that allow students to learn actively throughout the PD course. The observations of the study showed that teachers also use the teaching methods used in professional development in their own lessons. Additively, teachers developed new strategies similar to those used in the professional development course and implemented them in their classrooms. The teachers' practical experience of teaching strategies enabled them to renew their knowledge of how to learn better. They developed and implemented these new student-centered methods. Moreover, the teachers considered their students' learning as a process. They preferred to apply student- centered approaches where they could make better observations about student learning. The teachers' self-evaluation of their practices and writing reflective diaries also contributed to the application process of the new methods.

Secondly, the findings demonstrated that the professional development contributed to the teachers' assessment and evaluation practices. During the professional development course activities conducted with teachers on different assessment tools and the use of them. Later, in their STEM lessons, teachers use the instruments to analyze the students' learning in depth. Also, teachers create assessment tools that are consistent with the learning objectives. They benefited from the resources provided to them by the researcher.

Third, it is evident from the data that the professional development program contributes to the teachers' use of technology. However, the teachers used technology in their lessons to present their students with information from different sources and to relate their students' existing knowledge and abilities with new content.

Fourth, results of the study showed that the professional development program contributed to the collaborative work of teachers. The teachers prepared lesson plans in cooperation. They developed solutions by discussing together how they could solve the problems they encountered during their implementation. The teachers considered collaborative working model is productively. They especially emphasized that their collaborative work, which was fed from each other's experiences, beliefs, and knowledge, increased their own knowledge.

Fifth, the teachers' understanding of STEM education have evolved. Before the study teachers define integrated STEM education with only an engineering-centered pedagogical approach. They have been introduced other approaches (mathematical modeling, problem-based approach, etc.) during the research. Observations of the classes showed that teachers adopted new approaches and included the learning outcomes from all disciplines.

Additionally, regarding the lesson plans, they mostly included the learning outcomes related to the discipline of mathematics. This shows that the teachers were able to see the professional development and integrated STEM education in a more inclusive way. Their ability to make connections among STEM disciplines has been developed.

In summary, the findings indicated that the PD contributed the teachers' practices regarding STEM education in many aspects. It is observed that teachers mostly aim to design an inclusive education that provides active participation of students and prioritizes students' learning. Additionally, teachers' awareness of the influence of their own knowledge, skills, beliefs on teaching deepened.

Results of the study showed that teachers' professional knowledge, beliefs and practices can be developed throughout trainings which may be enhanced by features such as the following.

Knowledge Building: Based on the findings of the study, the perceptions, and misconceptions of teachers about STEM education were understood through pre-interviews with teachers, focus group studies, and learning activities in the first days of the professional development course. Therefore, the professional development program is structured on the teachers' existing knowledge, beliefs, and perceptions. Examination of teachers' existing

understandings make it possible to prepare content to develop teachers' beliefs and knowledge in a meaningful way and to support teachers' development individually.

In this study, the teachers first studied the theoretical bases of integrated STEM education, and then applied it in their classrooms. This has helped the teachers develop their understanding of STEM education. Teachers reflected on their own practices and evaluated their applications. Teachers also aimed to improve their own practice and increase student learning by following well-structured and applied STEM lessons. With the active participation of students, they have developed the teaching methods that are provided to learn by taking responsibility, by discussing possible methods to apply in their own classrooms. The professional development course's focus on practice as well as theory contributed to their practice in STEM education.

Collective Participation: The teachers worked in collaboration with each other and with the researcher during the professional development program. Their collaborative work has benefited teachers in two ways. The first is that teachers found the opportunity to learn reciprocally and contribute to each other's designs. Secondly an environment was created where the professional development of teachers is valued. The teachers discussed the methods they developed. They talked about the difficulties they encountered during the application, possible solutions and their suggestions of solutions. They learned from each other's experiences. Therefore, an environment supporting their own development has created within the system. The researcher helped them to see their newly developed knowledge and skills valued. The researcher helped them also feel supported, and therefore to be motivated to continue their professional development.

School-centered: Carrying out the professional development in the teachers' schools played an important role in the teachers' participation in a long-term program. In addition, this situation helped the teachers to set goals for their students while making their lesson plans. They were also able to discuss possible situations with each other and to take precautions. For example, Zeynep planned her lesson based on the region where the students live. She prepared the screenshots by considering the physical conditions and possible problems in the internet connection. The activity involved finding the location of Turkey and the province they are in with the Google Maps web application. Another example is that

Zeynep thought that the method developed by Merve to improve classroom management would be beneficial for her students and applied it in her lessons.

Sustained Duration: The teachers were given time to improve their knowledge and skills with the professional development course. They designed the first module within the professional development course with support of each other and the researcher. After implementing the first module, they discussed their own applications and worked on how it could be improved. Then they designed the next module. Thus, they began to see their development as a process. They expressed this view in the interview held at the end of the research. They stated that their reflection and self-evaluation skills developed.

Providing Sources: The findings of the study revealed that the resources provided to teachers on STEM education guide them in their practices. They improved their knowledge of teaching with the information they gained from the sample lesson videos in the professional development course. They adapted the teaching methods to their own teaching and used the provided documents while preparing their lesson plans and self-evaluation.

4.2.4. Summary of Results

4.2.4.1. *Research Question 1: Teachers' STEM PBs*

In summary, the teachers hold both constructivist and traditional beliefs about the nature of teaching and learning in STEM education. Additionally, the education of all teachers has traditional learning characteristics. These traditional learning experiences of teachers have played a role in structuring their beliefs. Furthermore, all of the teachers emphasized the necessity of applying student-centered approaches. Maintaining their belief in teacher-centered approaches, they attributed them to traditional teaching. They defined STEM education as innovative and constructivist.

The examination of the teachers' beliefs about the nature of STEM disciplines indicates that all the teachers have been exposed to traditional teaching throughout their experiences as students except for their limited incidents reflecting the constructivist approach. All teachers recall their limited amount of student-centered learning experiences with positive emotions and in detail. During the professional development course, teachers began to

develop a perception of the importance of in-depth and meaningful learning in mathematics and science teaching. However, they also preserved their traditional learning beliefs. Besides, in situations where environmental factors are not suitable, their traditional beliefs have guided their practices.

The teachers have misconceptions about engineering and technology disciplines. They expressed that their content knowledge is inadequate and their self-efficacy beliefs are at a low level. Poor conditions of schools have negatively affected teaching these two disciplines. Thus, they have excluded the learning outcomes in the later designs of the STEM courses.

The teachers took a more inclusive approach to STEM education. They recognized and implemented new student-centered pedagogical frameworks. Their past experiences come to the fore as the sources of their beliefs. Their experiences which they had when they were students and as teachers play an equal part in their thoughts. However, they often tend to remember positive teaching experiences. Additively, when they have conflicting beliefs, the context in which teachers work plays an active role in determining which beliefs will turn into practice.

Based on the observations, the conditions of teachers in the context of school and country have a negative impact on STEM education. In particular, the lack of adequate equipment in the school and insufficient family support and participation have revealed that it prevents teachers from carrying out comprehensive and qualified practices. In addition, compulsory curriculum, time lag, large class size are the other factors that negatively affect teachers to deliver quality integrated STEM education.

Results of the study showed that contextual factors have negative effect on teachers STEM education, innovative practices, and teachers' professional development. According to teachers these factors are unsupportive work environment, poor physical conditions of school, lack of support from community, compulsory curriculum, time lag between the curriculum and implementation and large class size. These barriers prevent teachers to deliver high- quality STEM education.

4.2.4.2. *Research Question 2: Teachers' Pedagogical Content Knowledge in STEM Education*

The results showed that the elementary school teachers had difficulty in defining STEM education comprehensively and in identifying appropriate pedagogical approaches for STEM education. They used to define a STEM education based on science and engineering, in which they included the discipline of mathematics with only some subjects. Prior to the professional development course, all teachers shared the conception that integrated STEM education is associate with engineering design cycle and hands-on learning.

Teachers developed their perspectives, pedagogical content knowledge and skills on STEM education during the professional development program. In addition, they deepen their knowledge of student, knowledge of context, knowledge of curriculum, knowledge of assessment and knowledge of 21st century skills to carry out STEM education more effectively. Teachers identified deepen students understanding by offering strategies for synchronizing standards across disciplines as important characteristic of STEM education. Therefore, they associated the learning outcomes with the classroom activities and assessments in their practices. Besides, they used student-centered approaches in their lessons. Thus, they designed a more inclusive education and perceived professional development as an ongoing process.

Moreover, teachers' beliefs sometimes precede pedagogical content knowledge. Their beliefs about nature of learning and teaching have prevented them from applying student-centered approaches and creating an environment that will provide students with 21st century skills. Additively, although the pedagogical beliefs of the teachers are constructivist, the practices of the teachers, which were deprived of the context that would enable them to practice these beliefs for a long time, turned into traditional practices by contradicting their beliefs in the process.

The findings of this study revealed important evidence for the relationship among the different characteristics of teachers. Analysis of the study indicated that, teachers may tend to reflect their traditional beliefs in their teaching when their context does not support the' use of effective methods. On the contrary, when teachers work in environments that support

their learning and development, they become more successful in preparing and implementing lesson designs that enable students to learn in depth and effectively.

4.2.4.3. ***Research Question 3: Influence of PD***

The findings showed that STEM-oriented professional development program contributed to the teaching practices of the teachers. Teachers' teaching methods and techniques have improved. Teachers' assessment and evaluation practices have advanced. Teachers used formative assessment approach and they aligned the assessment tools with the objectives of the lessons. Teachers developed their technology integration throughout the study. And finally, the professional development program has played a role in the improvement of teachers' understanding of STEM education.

The positive effects of the professional development program on the pedagogical content knowledge and pedagogical beliefs of the teachers may be due to the following features of the course. According to the findings of the research, for a professional development course to be effective, the points below should be taken into consideration:

1. Teachers' prior knowledge, interests, and areas where they want to improve themselves should be regarded.
2. New approaches should be provided not only to present the theoretical aspects, but also to experience their practices.
3. Resources should be provided to teachers. (Sample lesson videos, sample lesson plans, sample activities and problems, assessment and evaluation forms, self-assessment forms, etc.)
4. Professional development course should be carried out in the place where the teachers work, in addition the characteristics of the environment in which the teachers work should be considered.
5. Teachers should also be given the opportunity to experience the skills expected to be acquired.

6. Teachers should be supported during their practice.
7. The opportunity to work in cooperation should be offered.
8. Teachers should be given time.
9. Not only the pedagogical content knowledge of the teachers, but also their pedagogical beliefs should be taken into consideration.

5. DISCUSSION, CONCLUSION, AND IMPLICATIONS

The purpose of the current study was to investigate 1) the teacher's pedagogical beliefs of integrated STEM education, 2) their STEM Pedagogical Content Knowledge, 3) the way the professional development program is reflected in their classroom practices, and 4) conditions that enhances the teachers' professional development in STEM education. Data on teachers' STEM pedagogical knowledge were analyzed based on the theoretical frameworks of Pedagogical Content knowledge created by Shulman(1987) and Magnusson and colleagues (1999). The data on their pedagogical beliefs about STEM education were investigated based on the frameworks created by Schoenfeld (1998), Raymond (1997) and Aguirre and Speer (1999). The 3rd and 4th research questions were answered by considering the conceptual relationships and developments of teachers' pedagogical beliefs in STEM education, their STEM pedagogical content knowledge and classroom practices. In this section, the findings related to each research question will be discussed in relation to the existing literature and the conclusion. In addition, implications for educators, practitioners, and researchers in the field of education will be offered.

5.1. Elementary Teachers' Pedagogical Beliefs about STEM Education

According to the findings, the teachers' beliefs about integrated STEM education were related to the 1) nature of teaching and learning, 2) nature of STEM disciplines, and 3) to the context (Aguirre & Speer, 1999; Beswick, 2012; Ernest, 1989; Mosvold & Fauskanger, 2013; Raymond, 1997; Schoenfeld, 1998; Thompson, 1992) (see Figure 5.1).

In the studies that examine teacher beliefs in STEM education, it is seen that the scope of the beliefs is narrowly reported than this study and teachers' beliefs about the context are excluded (Acikgul Firat, 2020; Shahali, et al., 2015; Wang, et. al., 2020). The findings of this research have potentials to contribute to existing body of the literature by emphasizing teachers' beliefs more extensively including beliefs about teaching and learning, beliefs about the nature of STEM disciplines, perceptions about integrated STEM education, beliefs about the context and feelings and experiences about STEM disciplines.

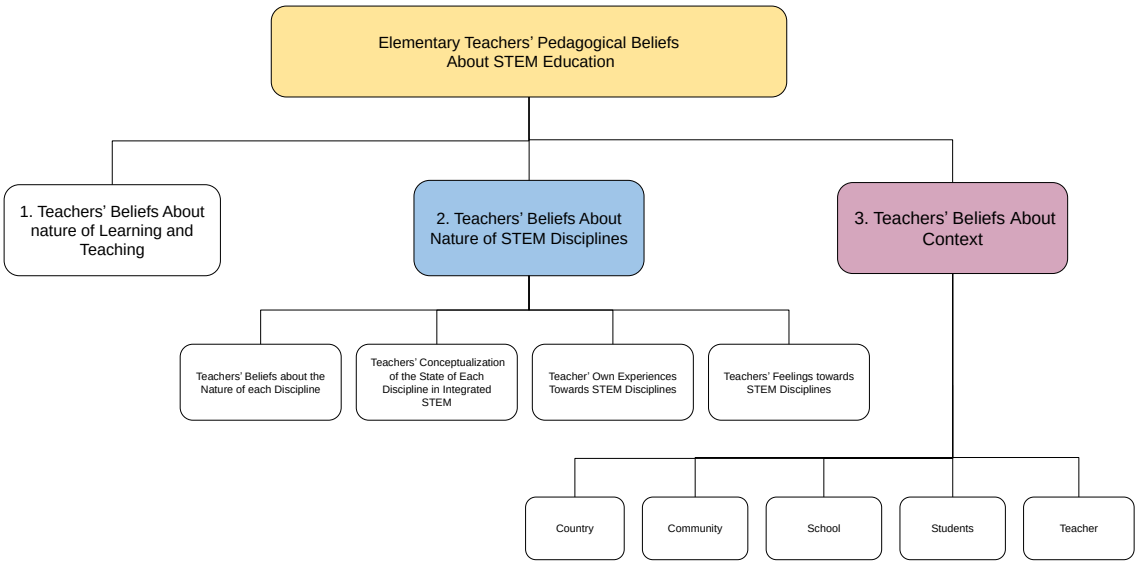

Figure 5.1 Elementary Teachers' Pedagogical Beliefs About STEM Education

5.1.1. Beliefs of Teachers Regarding Learning and the Nature of Teaching in STEM Education

The findings of the study revealed the teachers having both behavioral (traditional) and constructivist beliefs about STEM education. This finding confirms those of previous studies revealing the complexity and multifacility of teachers' beliefs about learning and teaching (Alkhateeb, 2019; Kutaka, et al., 2018; Lai & Lin, 2018; Polly & Hannafin, 2011; Yang et al., 2020). From a developmental point of view, constructivist beliefs considerably increased during the professional development course as seen in previous studies (See Figure 5.2) (Fitzgerald & Cunningham, 2013; Rich et al., 2017). This change in teachers' beliefs may stem from the fact that the professional development allows teachers to work collaboratively (Hiebert, et al., 2002; Donna, 2012). As also reported in similar intervention studies the professional development relates new content to their own knowledge and experience (Knapp, 2003; Opfer & Pedder, 2011), allows teachers to practice and reflect on their own practices (Franke et al., 1998; Joyce & Showers, 2002; Putnam & Borko, 2000). One

possible reason for this improvement is reported in a previous study as they apply what they learned from PD (Kurutas, 2017).

Teachers tend to idealize STEM education in their emerging beliefs. It is thought that this situation can be related to the beliefs of the teachers about the school, neighborhood, and country they work in. Similarly, previous studies have shown that teachers' professional development is affected by their beliefs (Muhtarom et al., 2019).

The results of the study showed that the teachers believe that integrated STEM education is effective which carry characteristics of constructivist approach. However, they stated that it is difficult to implement when their conditions are considered. In their study, researchers question the possibility of idealizing student-centered, constructivist approaches in science education (Anderson, 2002). To them, teachers over-idealize their constructivist approach due to the difficulties they encounter in reflecting on their classroom practices (Delice et al., 2013; Lumpe, et al., 2000; Windschitl, 1999). Results of the currents study are consistent with this view. It was also found out in this study that teachers idealized integrated STEM education.

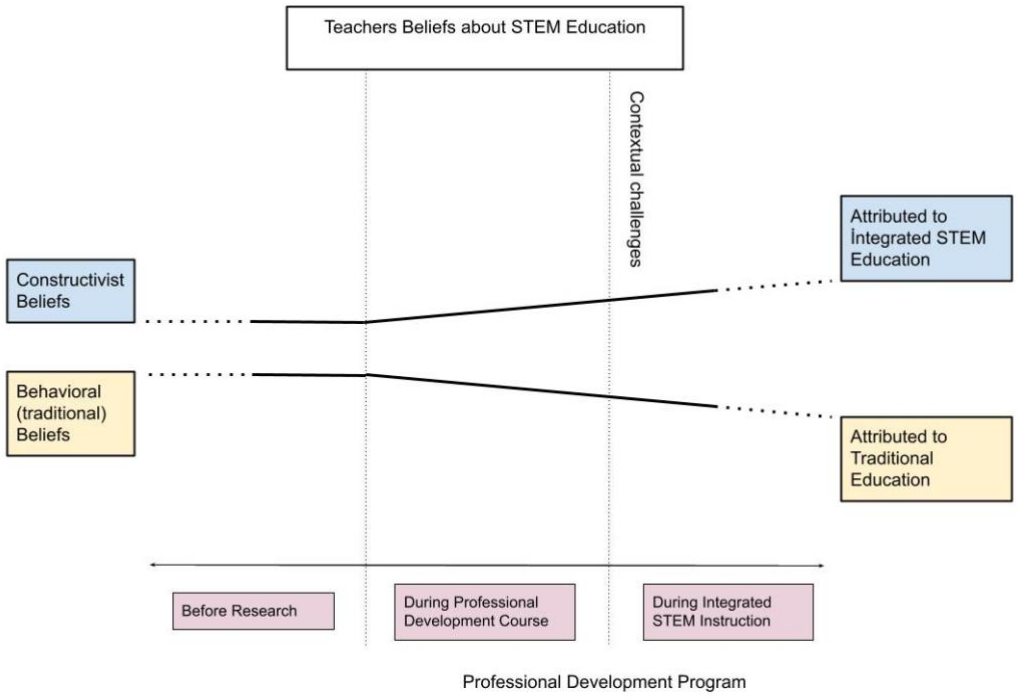

Figure 5.2 Development of Teachers' Beliefs over the Course of the Study

5.1.2. Teachers' Beliefs Regarding the Nature of STEM Disciplines

Data analysis showed that (1) teachers' beliefs about the nature of each disciplines, (2) their beliefs about the role of each discipline in integrated STEM education, (3) teachers' previous experiences in STEM disciplines, and (4) their feelings about STEM disciplines were effective in their beliefs about the nature of STEM disciplines (Calderhead, 1996; Cherrington & Loveridge, 2014; Ernest, 1989; Ertmer, 2005; McLeod & McLeod, 2002; Rich et al., 2017; Thompson, 1992). A change has been observed in the beliefs of the teachers participating in this research about the nature of the disciplines. After the professional development course, the teachers stated their beliefs about mathematical claims consist of a set of practices and structures created in relation to each other. To give an example, Merve explained that she believes "mathematics could be a tool for sensemaking". Zeynep argued the need of these disciplines to be taught in real life context. Naz started to develop beliefs about both mathematics and science as a reflection of the real world. However, she also kept her former beliefs about instrumental mathematics which focuses on operations and facts and memorization of procedures.

Previous research indicate that teachers' professional knowledge and belief can be improved through professional development courses (Kurup et al., 2019; Wang et al., 2020). The teachers associated the engineering discipline with the engineering design cycle, and technology with coding, prototyping, and the use of electronic devices. Though, it has been realized that their beliefs concerning engineering and technology are very limited and they have some misconceptions due to their inexperience in these disciplines as also reported in various studies (Brown et al., 2011; Owens, 2014; Paulson, 2005; Wang, 2012; Yildirim & Turk, 2018).

Analysis of the pre-interviews revealed that teachers' perception of STEM education focuses on science and engineering disciplines, did not include the objectives of technology course, and includes mathematics with limited learning objectives such as symmetry, numbers and operations. These findings are consistent with research showing that teachers' STEM lessons focus only one disciplines while no explicit attention paid to concepts from other disciplines (Bell, 2016; Roehrig et al., 2012; Turner, 2013). During the research,

teachers developed positive attitudes and beliefs towards the integrated STEM education, with a more inclusive and interdisciplinary emphasis on the role of disciplines in STEM education (Bektas & Aslan, 2019; Thomas, 2014). This situation is also beheld in other studies in the literature (e.g., Maass et al., 2019; Ring-Whalen et al., 2018). In this study, the interdisciplinary feature of STEM education, which is connecting the disciplines, is one of the most emphasized features by teachers as also observed in the study conducted by Ring-Whalen and colleagues (2018).

The teachers expressed the effectiveness of their experiences in STEM disciplines in their beliefs about STEM education. The teachers' experiences in STEM disciplines generally rooted during their student years. This result was predictable, and it is consistent with previous studies (Ertmer, 2005; McLeod & McLeod, 2002; Oskay et al., 2009; Perry & Rog, 1992; Rich et al., 2017; Sharp & Davis, 1997). They generally received education with a traditional approach (Barak, 2012; Jimoyiannis, 2010). Teachers have mentioned that the professional development programs in which they can develop their pedagogical content knowledge in STEM disciplines are very limited as also stated in previous studies (Altun & Cengiz, 2012; Recker-Hughes et al., 2010).

According to the findings of the study, teachers' feelings about STEM disciplines also play an active role in their thoughts. This confirms previous findings in the literature (Haciomeroglu, 2013; Swars et al., 2006). As teachers' knowledge of these disciplines generally develops during their teaching lives, their feelings generally develop in this process. This result shares similarities with the study conducted by Karaaslan (2003). Additionally, it has been found out through the interviews that teachers generally have negative feelings towards science and mathematics disciplines. This finding was echoed in other elementary teacher education studies. (Hadley & Dorward, 2011; Gresham, 2008).

5.1.3. Teachers’ Beliefs About Context

The current study revealed that teachers' beliefs about country, neighborhood, school, student, and teacher contexts might have an impact on their beliefs about integrated STEM education (Knoblauch & Hoy, 2008; Sen & Oztekin, 2019). The findings of this study shows that the education system of Turkey has a great impact on teachers' beliefs. Teachers expressed that they are expected to execute the content of predetermined curriculum in a

certain time and the high stakes exams prevents them from applying innovative approaches as reported in previous studies (Bakırcı & Kutlu, 2018; Buyruk, 2014). Participating teachers also stated that the professional development of public-school teachers in STEM fields is not valued enough (Bümen et al., 2012; Güven et al., 2010). They think that in the district where they work, parents prefer behaviorist teaching methods because of the high stakes tests to a student-centered education system adopting a constructivist and innovative approaches. Consequently, they conceive of that STEM education should be an education that excludes parent participation (Cosar & Demir, 2012; Dam, 2008; Yildirim, 2017). According to the teachers, physical inadequacies at school, class size and predetermined lesson hours are barriers for implementing innovative approaches. In addition, they do not have time to work collaboratively, discuss and develop practices of innovative approaches. These issues were stated by many researchers (Aydin & Boz, 2012; Cutter-Mackenzie & Smith, 2010; Dogan, 2005; Lee & Luft, 2008; Rollnick et al., 2008). Teachers think that students would learn more effectively from the socio-emotional point of view with integrated STEM education. They believed that the feedbacks they received from their students played an active role in continuing their integrated STEM education. It is possible to find support from studies in the literature on this subject. For instance, Limniou and colleagues (2018) set forth that students' preferences have an impact on teachers' teaching methods and techniques. Park and Oliver (2008), found in their study that students' questions guide the process of teaching in the classroom. Clearly, the feedback received from the students plays an essential role in determining the classroom practices of the teachers. In addition to the external factors, the teachers do not have enough content knowledge to guide their students in STEM fields. Therefore, they believe that they need support in applying innovative approaches.

Bandura (1993) claimed that the school environment has an impact on teachers' beliefs. According to Schoenfeld (1998), thoughts are often context-based. Similarly, the findings of this study indicated that the new beliefs that teachers develop regarding integrated STEM education are influenced by the contexts they are in (Jones & Leagon, 2014). Additionally, as suggested by Goodson (1991), analysis of interviews pointed up teachers tend to remember positive experiences longer. This finding is in line with the findings of Lee and Yin's (2011) study. It has been remarked by the researchers that the inability to understand

the feelings of the teachers will cause the professional development needs of the teachers to be misunderstood as well. Likewise, Girvan and colleagues (2016) also stated that the emotional and practical support for teachers plays a very important role in their professional development.

Finally, the findings of the study indicated the pedagogical belief sources of the teachers. These are the family, the teachers' own student experiences (primary school, secondary school, and high school), student experiences at the education faculty, interactions with colleagues, and professional development courses. Invariably, Levin (2015) divided the sources of teachers' beliefs into external sources (for example, structured knowledge) and internal resources (for example, personal experiences) (Levin, 2015). Levin and He (2008) pointed out that (a) their experiences as a student in family and K-12, and their experiences in education faculty, and (b) participating in theoretical studies in the field of education have approximately the same effect on the beliefs of pre-service teachers. Levin and colleagues (2013) found in their study that (a) their learning experiences at the faculty of education and (b) their family values and their experiences as a K-12 student were the most effective sources of their beliefs (55%). In this study, however, teachers' personal experiences as a student in K-12 and the beliefs they have developed while they are teachers are equally effective in shaping their beliefs about STEM education. The reason for this difference may be due to the fact that teachers have similar traditional learning experiences during their careers. Besides, this might be because they do not encounter challenge that will cause a change in their understanding and beliefs (Kagan, 1992; Tanase & Wang, 2010). As a matter of fact, teachers' beliefs about teaching date back to their student years (Donovan & Bransford, 2005; Lortie, 1975; Pajares, 1992).

5.2. **Elementary Teachers' Pedagogical Content Knowledge of STEM**

Studies examining the features of integrated STEM education have been found to emphasize the importance of a STEM PCK framework developed based on teachers' practices (e.g., Capobianco & Rupp, 2014; Johnson et al., 2015). As stated in the previous sections, PCK is a combination of field and pedagogical knowledge specific to teachers (Shulman, 1987). The definition of PCK of STEM is discussed in detail in the conceptual framework section (Bray, 2011; Grossman, 1990; Hill et al., 2008; Magnusson et al., 1999;

Saxton et al., 2014; Scrinzi, 2011; Srikoom et al., 2018). In the light of the aforementioned literature, the pedagogical content knowledge of STEM of the teachers were examined in the following sub-dimensions (See Figure 5.3):

- Teachers' Orientation Towards STEM: Teachers' approaches to the role of disciplines in STEM education and to the nature and integration of STEM disciplines
- Knowledge for Teaching: Information about the methods and strategies that teachers use in the planning process, creating an integrated curriculum, information about students' thinking processes, and assessment and evaluation approaches
- Knowledge of Context: Teachers' knowledge about the socio-cultural structure; country, region of residence, school, student, etc.
- Knowledge of Integration: Integration of technology and knowledge of teachers to teach by integrating STEM disciplines
- Teachers' Developmental Knowledge: Teachers' professional knowledge and 21st century skills that develop in parallel with the developing technology

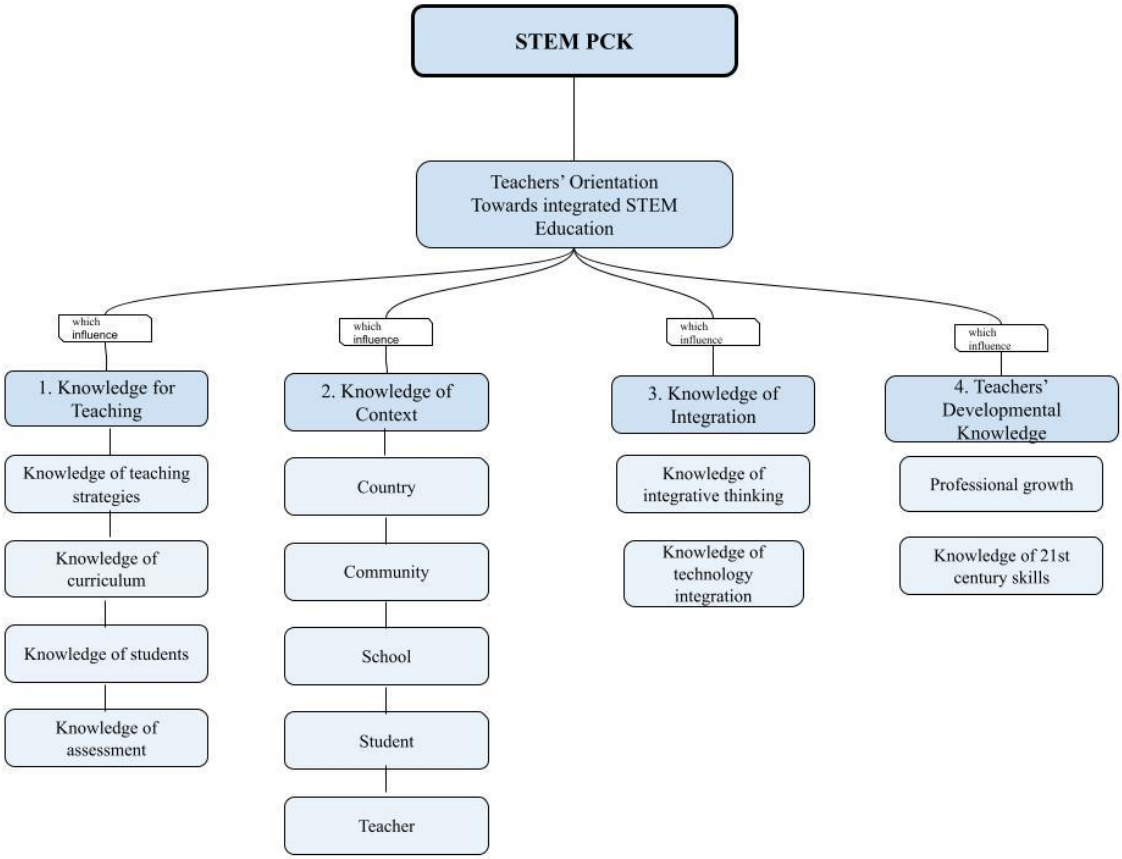

Figure 5.3 Elementary Teachers' STEM PCK

5.2.1. Teachers' Orientations Towards Integrated STEM Education

Preliminary interviews with teachers revealed they have specific approaches about how to integrate disciplines in integrated STEM education. In this approach, which disciplines will be focused in STEM applications and teaching approaches that are targeted to be used are in question. For example, a review of the Zeynep's STEM lessons revealed that she paid attention to the science discipline, and she adapt problem-based approach. She focused on a problem in the science discipline and taught to solve the problem with the utilizing concepts of other disciplines. Merve has an approach wherein she organized her integrated STEM modules around science problems and issues. Merve mostly teaches with problem-based and used context integration approach. On the other hand, Naz has defined STEM education based on the engineering design cycle and problem-based learning approaches and used

context integration, in which the science is given explicit attention. The examinations of the lesson plans and lessons of the teachers indicated that STEM applications were made in parallel with teachers' orientations. Obviously, teachers' definitions of STEM education reveal their general ideas about it and how they conceptualize STEM education as stated in the literature previously (Roehrig et al., 2021; Grossman, 1990). According to the findings of the current study, teachers' approaches to STEM education can influence their educational decisions. Our findings are consistent with the findings of the Grossman's model (1990) and consensus model of PCK developed by a group of PCK researchers (Gess-Newsome, 2015). Orientations has been introduced as a component of science PCK by Grossman in her seminal work. According to her, orientation refers to teachers' knowledge and beliefs about the purposes and the goals for teaching science at a particular grade level (Grossman, 1990). Similarly, in the current study, teachers' orientation towards integrated STEM education has been emerged as a component that represents teachers view or conceptualize integrated STEM education. In other words, teachers' orientations regarding integrated STEM education can be effective in the teachers' planning of modules and in determining the learning outcomes they believe to be beneficial for students. Moreover, these orientations also have an impact on their decisions in the assessment (Borko & Putnam, 1996; Magnusson et al., 1999). The role of orientations toward STEM is in line with Radloff and Guzey's study (2016). Researchers worded that there are very different perceptions and understandings regarding STEM education and the difference in STEM understanding may be reflected in the practices of teachers.

Ring- Whalen and colleagues (2018) stated that different conceptual models of integrated STEM education were reflected in teachers' creation of curricula. Researchers focused on the explanation of the roles of each discipline in integrated STEM education (Ondes et al., 2019; Rockland et al., 2010). Others focused on several teaching methods that can be used in STEM education (Stohlmann et al., 2012). Our study confirms the results of those aforementioned studies and provides the basis for a new way to analyze teachers' conceptions of STEM education. Table 5.1, below, provides teachers orientations toward STEM education with dimensions revealed in this study.

Table 5.1 Teachers' Orientation Towards STEM

Way of integration	**Content integration**		**Context integration**	
Central disciplines	Single discipline is central		Two disciplines are central (e.g., M-S, S-E, E-T)	
Approaches of Instruction	Project based learning	Engineering design process	Mathematical Modelling	Problem based learning
Important Student Outcomes	Active learning	Problem solving/ reasoning	Entrepreneurship	Creativity

As seen in Table 5.1, the teachers' orientations towards integrated STEM education were analyzed from 3 perspectives. As Magnusson and colleagues (1999) expressed, the difference that separates the teacher's orientation from the teaching methods is their purpose to apply this approach. The teachers gave different instructions in their classrooms in relation to their specific STEM orientations (Capobianco & Rupp, 2014).

The results of the study showed that the orientations of the teachers regarding integrated STEM education improved. Teachers perceive integrated STEM education not as teaching science related to other disciplines, but as teaching the science, mathematics, engineering, and technology concepts in collaboration with each other. As proposed by Roehrig and colleagues the evidence we found points that professional development may help teachers to facilitate higher quality integration in their STEM designs (Roehrig et al., 2012). However, the teachers adopted the content integration approach while integrating disciplines in STEM education. This may be because teachers learn STEM education popularly at first,

not by receiving any professional support through professional development programs (Asik et al., 2017). During the research, the teachers applied their changing understandings to their teaching by defining a more inclusive STEM education compared to the pre-research. They included the subjects in the mathematics discipline in their lesson plans. They also considered the adopting approaches such as engineering design cycle and mathematical modeling. As also observed in this study, previous research has presented improvement of teachers' perceptions regarding STEM education (Han et al., 2015; Nadelson et al., 2012).

5.2.2. Teachers' Knowledge for Teaching

This component of STEM PCK refers teachers' instructional strategies consisting of curriculum information, student information, assessment, and evaluation information. This factor forms the basis of STEM PCK (An et al., 2004) and is supported by the theoretical framework proposed by Chan and colleagues (2019).

Teachers' Knowledge of Teaching Strategies

Analysis of the data revealed that teachers mostly focused subject specificstrategies related to science and mathematics disciplines and partially engineering disciplines. Teachers' instructions were also reviewed from a point of view that promotes teacher-centered or student-centered teaching approaches. All teachers focused on different teaching strategies. Data analysis revealed that Merve focused mostly on student-centered strategies. Naz enabled students to be active with student-centered hands-on activities. However, she did not associate the activities with the standards, and implemented teacher-centered practices. Zeynep, on the other hand, mostly used teacher-centered methods in her later lessons, as she thought that her students were not learning well enough and their readiness was lacking in student-centered practices. The tendency of teachers to use mostly teacher-centered approaches has been the subject of many studies in the literature (Meis Friedrichsen & Dana, 2005; Koballa et al., 2005; Magnusson et al., 1999). The difference in their classroom practices may be due to their orientation towards STEM education as argued in other studies (Barkatsas & Malone, 2005; Thompson, 1984). Thus, Naz stated the importance of her students are being active during the integrated STEM education. Accordingly, she created an atmosphere suitable for collaborative learning and students were able to actively engaged with the course. However, Naz did not associate these activities

with standards in her STEM lessons. Her teaching methods were more aligned with hands-on activities than integrated STEM education. One explanation for this might be that Naz created integrated STEM modules by planning activities first, learning goals second. Similarly, researchers stated that elementary teachers primarily consider activities and what they will teach later (Beskese, 2019; Sawyer and Myers, 2018). Merve generally focused on problem posing and problem solving activities as these teaching methods were aligned with her STEM education orientation. In addition, she emphasized entrepreneurship in her lessons as she stated the importance of students taking responsibilities of their lives and using effective inquiry process. Zeynep stated the goal for integrated STEM education is to defining and solving problems. Thus, Zeynep focuses on understanding the problems very well and solving problems with different methods. The findings indicates that teachers' approaches to the goals of STEM education may have a decisive feature in their lesson planning in parallel with previous studies (Bartels et al., 2019). Another reason for the difference in the teaching methods of the teachers may be the difference in their background as stated in the literature (Eick & Reed, 2002; Tekin-Striva, 2014). The other possible reason might be lack of opportunities to apply student-centered approaches as is also stated in the literature (Flick, 1996; Ozel, 2013).

Investigation of the subject specific strategies of the teachers reveled that they employed insuffficient subject-specific strategies, in particular representations, and limited with mathematics discipline (among all other subject specific strategies, such as learning cycle, discovery, activities etc.). Teachers choice of subject specific strategies reflects their knowledge they have acquired during their own K-12 education. However, researchers indicated that teachers' use of representations of concepts is an indispensable part of mathematics lessons (Akkus-Cikla, 2004; Ball, 1990). Their limited use of subject specific strategies may indicate that they do not have deep subject matter knowledge (Lesh et al., 1987; Ma, 2010; McDiarmid & Wilson, 1991). And previous studies indicated that teachers' use of limited representations may also be the reason of the lack of opportunities to develop their PCK during their carreer (Isiksal, 2006; Kurt, 2006; Pusmaz &Kupcu, 2010).

Findings of the study show that teachers' designs are categorized as misapplication lessons. For instance, the courses that the teachers describe as the engineering design process are material design. The courses that they describe as mathematical modeling are word

problems with concrete materials (mathematical manipulatives). In compliance with the applications of integrated STEM education, similar findings are encountered. Mohr-Schroeder and colleagues (2015) expressed that perceptions regarding STEM educationmay lead to wrong practices. According to Guzey and colleagues' study that investigates designs of teachers' STEM lessons (2014), STEM lessons missing the natural connections and oppoortunities to integrate STEM subjects into their engineering challenges. Similar to ours, in their study, researchers concluded that even though the missapplication lessons are engaging science activities, they are far from allowing students to discover STEM concepts.

Results of the study revealed that the teachers used the strategies they experienced in the professional development course.They also adapted the to their lessons in a way that would increase student participation. A similar result is also encountered on the examination of the literature on professional development courses aimed at improving teachers' knowledge of instructions. The teaching strategies that teachers learn during the professional development course are reflected in their teaching (Costa & Domingos, 2017; Zehetmeier & Krainer, 2011).

Teachers' Knowledge of Curriculum

The analysis of the data revealed that the teachers were generally well-informed about the subjects and learning outcomes of the curriculum and they stayed up-to-date with the latest changes in the curriculum.Seminars held at the beginning and end of the semester are shown as a reson for teachers developed knowledge of curriculum in the literature (Kahyaoglu & Karatas, 2019). Teachers STEM lessons showed that the learning outcomes are parallel with the compulsory curriculum. Teachers stated that they felt too constrained by current school structures and policies to apply to the integrated STEM modules. This is a well known and well studied issue in Turkish education system. Researchers identified that the compulsory curriculum and time lag are some of the main problems that prevent teachers to apply students-centered methods as in the current study (Korkmaz, 2009; Yurdakal, 2018). Nonetheless, teachers have difficulty in finding resources related to the discipline of engineering and technology. Teachers are not given any opportunity to learn engineering and technology concepts and pedagogical content knowledge in these areas is one of the reasons as stated in previous research (Kaya et al., 2004; Uçar & İpek, 2006). It is also

because of the inadequacy of quality resources and lack of written curriculum for teachers to use in teaching these disciplines (Aslan-Tutak et al., 2017; English, 2016; Köse & Uzun, 2020; MEB, 2016).

Teachers' Knowledge of Students

Results of the study showed that teachers designed their lessons by considering the interests of their students. They mostly do not provide instruction that addresses their learning difficulties and misconceptions. Researchers have specified that teachers should be competent about students' understanding. Teachers should know which subjects students have difficulty in learning, and how to overcome these difficulties (Fennema & Franke, 1992; Shulman, 1987). An and colleagues (2004) refers that there are 4 dimensions of knowledge of students in PCK. These are building new knowledge on students' existing knowledge, understanding students' misconceptions, enabling students to learn and improving students' thinking. The inability of teachers to design an instruction that addresses the learning difficulties and misconceptions indicates that they have very limited pedagogical content knowledge. Teachers do not develop enough knowledge of student during their education and professional development at the university. They generally use the representations and models presented to them during their K-12 education. Teachers lack of knowledge of student has been highligted in several studies (Aydemir, 2014; Isiksal, 2006; Kurt, 2006).

During STEM practices, the teachers use assessment tools that enable them to monitor student learning more closely. Consequently, they gain new insights about their students. They observed that (1) students' reading comprehension skills influence their STEM success, (2) that students' verbal expression skills are better than their written expression skills, and (3) that students in their classes who had low success, increased their learning and participation during STEM practices. Using formative assessment provides detailed information about students' thinking and reasoning processes and learning as seen in many studies (Bell & Cowie, 2001; Clinchot et al., 2017; Ruiz-Primo & Furtak, 2007).

Teachers' Knowledge of Assessment

The results showed that elementary teachers had very little knowledge about the purpose of the assessment and approaches to summative and formative assessment at the beginning of the current study. As indicated by many researchers, assessment and evaluation are expected to be compatible with the educational goals, to guide the learning process, and to increase learning (Bell, 2007; Sadler & Zeidler, 2009; Shwartz et al., 2013). The lack of assessment knowledge of teachers was also emphasized in other studies and the necessity of continuing professional development programs was suggested (Tacoshi & Fernandez, 2014). It is evident from the data that Merve's and Zeynep's knowledge of assessment improved during this research. However, Naz had difficulties while planning the assessment methods for the STEM modules. Merve and Zeynep have set assessment goals consistent with the learning objectives of their courses. They have guided their instructional designs that mostly follow students' learning and progress with the information they obtain. As the teachers utilize the formative assessment strategies, their teaching has improve simultaneously throughout the study. This result confirms previous findings in the literature (Lee et al., 2007; Van Driel et al., 2001). Contrarily, Naz's inability to design integrated STEM modules negatively effected her assessment process. As she designed lessons as isolated hands-on activities she was enable to set assessment goals conistent with the learning objectives. In the literature teachers' inability to set assessment goals are being related with their conceptualization of STEM education (Bell, 2016; Cunningham & Carlsen, 2014; Dare et al., 2018).

5.2.3. Teachers' Knowledge of Context

The teachers' learning environments are very importation for their teaching. Findings regarding teachers' knowledge of context overlap with those of Land and Drake (2010) and Smith (2012). As these studies also highlighted, the results of the current study revealed that teachers' perception and interpretations of existing resources define their instructional goals. According to this study, teachers' knowledge of country, region, school, student, and teacher have an impact on STEM education (Feldman & Herman, 2015; Sen & Oztekin, 2019). The teachers stated that their professional development as public-school teachers are not valued enough. Belatedly, they develop more effective teaching in environments where they feel supported and the importance of valuing the development of teachers (Knobloch & Whittington, 2002; Rose, 2001). As reported by Collie and colleagues (2016) and Ren and

Smith (2017) the evidence we found that shows if teachers feel supported, they are more inclined to implement student-centered approaches.

The teachers expressed that the lack of adequate equipment in the school and the lack of family support and participation prevented them from carrying out comprehensive, qualified practices. They could not implement these student-based practices because of the external factors such as compulsory curriculum, the course hours that do not allow long project-based teaching and the overcrowded class size. The negative effects of the contextual factors are consistent with previous studies (Arzi & White, 2007; Barnett & Hodson, 2001; Cochran, 1992; Grossman, 1990). The findings of the research are in line with other studies showing the effect of context on education (Darling-Hammond, 2006; Fenwick & Cooper, 2013; Teese & Polesel, 2003).

5.2.4. Teachers' Knowledge of Integration

Teachers' Knowledge of Integrative Thinking

In the literature, focusing on the content of one discipline and using context from other disciplines to make the content more relevant is defined as "context integration" (Bryan et al., 2015). Though, a well-structured integration is essential for effective STEM education, and the way to this is through "content integration". By "content integration", researchers mean the units and activities consisting of a few of the STEM disciplines. Content integration focuses on "big ideas" and concepts from multiple disciplines. The findings of the study have revealed that teachers focus on instruction within one domain (usually mathematics or science) while supporting the content with implicit connection to the other disciplines. Teachers' integration method is identified as content integration. In addition, the teachers mostly do not include the learning outcomes of technology and engineering discipline in their lesson plans. According to the literature, there is a need for a teaching that allows students to learn from their mistakes and redesign with engineering design-based activities. This requires learning the content in mathematics and science with student-centered methods (Moore et al., 2014). However, the teachers' STEM integrations were not designed to allow in-depth learning of content in all disciplines (Moore & Smith, 2014; Smith & Karr-Kidwell, 2000). Studies have drawn attention to the lack of high-quality STEM curriculum that provides effective teaching in four disciplines. Also, teachers' lack of

content knowledge about these disciplines are shown another reason in the literature for their choice of integration method (Fairweather, 2008; Isaacs et al., 1997; Streveler, 2012, Smith & Pilotte, 2012; NRC, 2011).

Teachers' Knowledge of Integration of Technology

Results of the study showed that the teachers do not possess comprehensive knowledge, skills and competencies to integrate technology discipline into their teaching. Our results are consistent with the current literature (e.g., Adiguzel, 2010; Yildirim, 2007). Environmental barriers (such as lack of internet, lack of sufficient hardware materials, etc.) and lack of teacher knowledge (TPACK, pedagogical knowledge, etc.) may be the possible reasons for this result (Ertmer, 1999, 2005; Hew & Brush, 2007). In addition to these barriers, researchers explained lack of technology integration in education with pedagogy-based beliefs (Chen, 2008) and professional development barrier (Eren, 2014). Integrated STEM education requires teachers to keep up with continuous technological advances as suggested earlier in the literature (Akpinar, 2003). There are two ways to achieve this: pre-service training and in-service training (Eren, 2014; Fisher, 1997; Lambdin, 1997; Parker, 1997). Teachers who participated to current study do not have any formal education in the technology field. Teachers stated the lack of information technology course in their curriculum during their college years. And there are three reasons for their inability to develop their knowledge and skills during their career. These are (1) the lack of technology-related standards in the curriculum, (2) teachers negative mindset about the opportunities to teach technology and (3) the limited access of professional development opportunities for public school teachers. The findings of the study promotes the findings of studies investigating the causes for teachers' inadequacy in technology teaching (Baki, 1996; Erdogan; 2007; Scrum & Dehuney; 1997; Yildirim, 2007). As proposed by Ozel and colleagues (2008), the findings we found points to teachers' access to technology, training and technical support are prerequisities for effective technology integration.

Furthermore, findings of the research revealed that teachers benefited from technology in 3 ways. First of all, they often use technology at the beginning of the lessons to show their students an image or watch a video by using technology to attract students' attention to the subject. Secondly, the teachers used applications such as Ms Word, Ms Excel and web tools

during the lesson plan preparation. Finally, they benefited from cloud technology during the professional development course. In her study Kurutas stated that participant teachers underlined the need for having one common online platform that teachers can share, load, interact about their projects (2007). Similarly, in this study it is found that teachers utilized cloud technology to share their projects and interact. After the research, they stated that they would prepare their own projects and presentations by using the data. The findigs reported in the literature about how teachers use the technology in their STEM lessons coincides with the findings of this study (e.g., Kilinc et al., 2018; Kolburan Geçer & Bakar Corez, 2019; Korkmaz & Tunc, 2010).

5.2.5. Teachers' Developmental Knowledge

Teachers' Professional Growth

The findings of this research revealed that elementary teachers need ongoing support in integrated STEM education. The need for continuing professional development in STEM education is the subject of many studies (Asgar et al., 2012; Gillespie, 2015; Landicho, 2020; Polly et al., 2014). The professional development was perceived as an element of STEM PCK. Studies have emphasized the importance of continuing support for teachers' implementation to be successful in STEM education. For instance, Stohlman and his colleagues (2012) identified teacher support as a component in the model they developed for effective STEM education. Researchers claim the importance of creating time for teachers to work in collaboration, providing opportunities for collaboration with other schools and universities, and participating in training provided by companies. Accordingly, Corlu (2017) defined sustainable in-service training as an indispensable part of STEM education. Thus, he sets the goal of establishing a learning culture in the institutions (Corlu, 2017). Similarly Caner (2021) stated "valuing professional development" as one of the components of STEM teacher competencies framework in her recent study.

The teachers stated that they needed more support in three areas. These areas include (1) developing content knowledge in STEM disciplines, (2) applying the student-centered approaches that are part of integrated STEM education, and (3) planning STEM instruction for their students' needs (Brophy et al., 2008; Bush et al., 2020; Lee et al., 2018; Polly et al., 2014). According to the findings of the study, the teachers' need for continuing professional

development stems from their lack of knowledge in STEM fields (content knowledge) and the inability to receive training in accordance with the changes in teacher training institutions. It might be also because the teachers have received only discipline-based education during their pre-service education (Ceran & Cagirgan Gulten, 2017). According to the literature, the professional development needs of teachers in STEM education stem from the inadequacy of pre-service professional development opportunities (Blackley et al., 2017; Radloff, Guzey, 2016; Rinke et al., 2016; Ryu et al., 2019; Teo & Ke, 2014).

Multiple methods were used to support the professional development of the teachers in this study. These methods are the two-week professional development course and the ongoing collaboration of the researcher and the teachers during the STEM practices.The methods also include the collaborative work of the teachers and the teachers' reflective journal writing practices. The teachers mentioned that these methods strengthened their beliefs about STEM education.These methods had a positive impact on the permanence of their practices. This finding of the study is similar to the results of studies by Brown and Bogiages (2017), Estapa and Tank (2017), and Myfadden and Roehrig (2017). Furthermore, the teachers attended a long-term professional development course for the first time with this study. After the study, data analysis showed that they perceived their professional development as a process and made professional development plans for themselves. According to the findings of other studies, teachers who once had the opportunity for professional development, later became more open to the idea of professional development (Clements & Sarama, 2016; Edmondson & Choudhry, 2018; OECD, 2009; Pittman, & Gaines, 2015; Thompson & Kaufman, 2013). Results of the study indicated that the teachers' ability to work cooperatively increased and their research skills improved. They expressed that they aim to conduct studies to share their good practices in scientific meetings and professional development communities (Scientix, e-twinning, etc.). The collaborative approach used in this study might encourage teachers to support each other as learners. The teachers put forward that the ongoing sharing environment and the ongoing support of the researcher made them feel the support they needed. The findings of the study are similar to those of studies showing that teachers' knowledge and skills improve when they work collaboratively (Hord, 2009; Smith, 2014).

Teachers' Knowledge of 21st Century Skills

Teachers designed acvities for students to develop collaboration, life and career skills, problem solving, critical thinking, creativity and innovation and communication skills. Teachers did not evaluate the learning outcomes in 21st century skills, however they designed their plans by associating the learning outcomes in their courses with 21st century skills. Studies have also emphasized that there is a natural connection between STEM education and 21st century skills. STEM education leads to the teaching of 21st century skills (Beskese, 2019; Beswick & Fraser, 2019; Bybee, 2010; Khalil & Osman, 2017). However, in some lessons, Naz and Zeynep treated these skills as teacher-centered. These skills should be taught in a student-centered manner due to environmental difficulties (crowded class size, physical conditions of the school, etc.) and difficulties encountered in classroom management. Studies have revealed the necessity of student-centered, inclusive, and personalized learning environments in the teaching of 21st century skills (Cookson, 2009; Davies & Ryan, 2011). As Ohler (2009) mentioned, the role of teachers in teaching 21st century skills should be "the guide on the side, rather than the technician magician" (p.13). Teachers' approaches may have led to limited opportunities for students to develop 21st century skills as indicated earlier (Gut, 2011). Why teachers cannot apply student-centered approaches in teaching 21st century skills may be because of the poor classroom conditions and the difficulty of accessing qualified resources (Kereluik et al., 2013). Result of the study confirms previous findings in the literature and showed that the teachers developed 21st century skills such as collaboration and problem-solving skills during the research (Kim et al., 2019; Pellegrino, 2017; Saavedra & Opfer, 2012; Zorluoğlu et al., 2021).

5.3. Impact of and Conditions for Nurturing Professional Development Course on Teachers' STEM PCK, STEM PB and Classroom Practices

According to previous research, effective professional development programs can change the classroom practices of teachers (Darling-Hammond, 2009; Desimone, 2009; Smith, 2014). The teachers benefited from student-centered approaches in STEM education and used process-based assessment and evaluation methods. The change is observed in teachers' practices who use more teacher-centered teaching strategies and outcome-based assessment and evaluation approaches before participating in the professional development

course. This might be because of the characteristics of the professional development program. As mentioned before, a professional development training program was implemented. This program was based on theory and practice and built on teachers' knowledge and beliefs. It was designed considering teachers' individual development needs and conditions. It gave an opportunity to think about teachers' practices. The results point out the probability that professional development program has motivated teachers to perform best practices as it is comprehensive and provides active learning settings (Birman et al., 2000; Cohen & Hill, 2000; Kurutas, 2017; Richards & Farell, 2005).

Results of the study revealed that the professional development programs have changed the classroom practices of teachers. Developing areas of in class practices of teachers are teaching methods and techniques, assessment practices, use of technology, their collaboration, and understanding of STEM education. The programs were designed to improve teachers' pedagogical belief and pedagogical content knowledge. It created awareness about how students learn. The findings of this study confirm previous studies (Garet et al., 2001; Supovitz & Turner, 2000). During the research, teachers started to design STEM modules. These modules included teaching methods specific to STEM education (engineering design cycle, problem-based learning, mathematical modeling, etc.). They integrated 21st century skills, built strong interdisciplinary connection, and use technology to present information from different sources.

The teachers' knowledge of two areas is not reflected in the practices of the teachers even though they were aiming to be developed within the professional development course. These are knowledge of representation and knowledge of integration of technology. This may be because of their lack of content knowledge (Even, 1993). Another reason may be environmental conditions (Sen & Oztekin, 2019).

While it is not within the scope of this research to evaluate whether the students' knowledge and skills develop, it was concluded that students improved their collaboration skills, problem solving skills, and knowledge and skills in mathematics and science disciplines with the integrated STEM modules. According to teachers' observations the students developed positive attitudes towards mathematics and science. Similar to teachers' view, studies demonstrate that students feel more confident in science and mathematics

disciplines with integrated STEM education and develop positive attitudes towards these disciplines (Ince et al., 2018; Simsek, 2019). This may be due to teachers' feelings of more competent in science and mathematics teaching with the professional development program. Their innovative, student-centered approach is applied in their lessons (Desimone, 2009; Smith, 2013).

The characteristics of effective professional development programs have been studied for a long while (Borko, 2004; Cohen, 1990; Darling-Hammond, 1995; Desimone, 2009; Fenemma et al., 1996). Researchers have agreed that a professional development program should be long-term and consistent, should allow teachers to work in collaboration, should be considering the working conditions of teachers. Therefore, it might be enabled teachers to improve their knowledge, beliefs and practices. Effective PD should also allow teachers the achito practice newly learned methods (Porter et al., 2000; Kurutas, 2007). In addition to these, presenting quality resources for integrated STEM education is another method that supports teachers' practices. Similarly, Stohlman and colleagues (2012) expressed that providing resources and materials will help teachers to be successful in STEM implementation.

An international perspective indicates that teachers in Turkey are disadvantaged because they don't have access to high-quality PD (Aydin & Kilic Ozmen, 2009; Kacan, 2004). In developed countries (for example, USA, Canada, Finland, etc.), teachers have opportunity to participate in well-designed, long-term professional development programs. These programs take place in their schools and are planned by experts. Contrarily, in Turkey, professional development programs, are compulsory programs with pre-prepared content. They are generally carried out centrally. They are based on lectures and do not include an implementation process or practice-based content (Buyuksahin, 2018). With the professional development program developed and implemented in this research, teachers participated for the first time in a long-term program. According to teachers, they continually learned and worked collaboratively (Putnam & Borko, 2000; Fenemma et al., 1998). They feel that their professional development is not valued before the research. Prior to this research, teachers worked individually, they tried to provide an education in accordance with the compulsory curriculum. In addition, they generally used teacher-centered teaching approaches. Although they believe that it is important for students to learn by questioning, doing, and living, their

contextual beliefs were more effective in routing their classroom practices. They were using traditional teaching methods mostly fostering the rote learning of students. Similar findings were reported in previous studies (Friedrichsen & Dana, 2005; Küçükaydın Alkış & Sağır Uluçınar, 2017). In this research, teachers worked on pedagogical approaches in student-centered integrated STEM education. They watched and discussed effective implementation videos. They planned and developed their own practices together. They supported each other. Moreover, the teachers reflected upon their own practices. These approaches have provided a change in the environment of teachers. As also seen in previous studies, teachers have stated that their motivation to improve their professional knowledge has increased in this new environment in which development and learning are valued (Buyuksahin, 2018; Jones & Carter, 2007). The teachers try to understand their learning processes and so they improve their effective learning. The effect of reflection has been found to be essential in teacher practices (Banilover et al., 2007; Garet et al., 2001; Supovitz & Turner, 2000). The motivation of teachers may have arisen from the professional development program designed by considering the teachers' background knowledge, interests, and their professional needs (Darling-Hammond, 1997; Desimone et al., 2002).

With the current research, a new context has been created for teachers to share, collaborate, develop, and reflect. Even though the teachers work in the same school system and with same students, this context give them freedom to develop their pedagogical content knowledge and beliefs in STEM education. In other words, as Smith (2015) mentioned, "because the content was situated in, and relevant to, their classroom practice, the teachers valued it more highly" (p. 231). This finding of the study supports the findings of the teaching in context theory developed by Schoenfeld (1998). According to this theory, teachers' knowledge, beliefs, and practices are intertwined and affected by each other. However, their conditions play a determining role in which knowledge and beliefs will be reflected in practice (See Figure 5.4.). Study findings reveal that the conditions of the teachers have an essential role in their practices. And working in an environment, where the development of their professional growth is supported, has enabled teachers to develop a positive attitude towards their profession as stated in the previous studies (Erdogan, 2003; Erten, 2002; Uljas, 200). As Sen and Oztekin (2019) mentioned in their research, teachers' knowledge of the context has an impact on their pedagogical content knowledge. Teachers

cannot eliminate the negative effects that may occur with context knowledge on their own. Therefore, by creating a positive learning environment, where teachers' professional development is valued, where they can consult when they need support, and where they can discuss new knowledge and skills they have learned, it can be ensured that they apply approaches supporting students' effective learning in their classrooms.

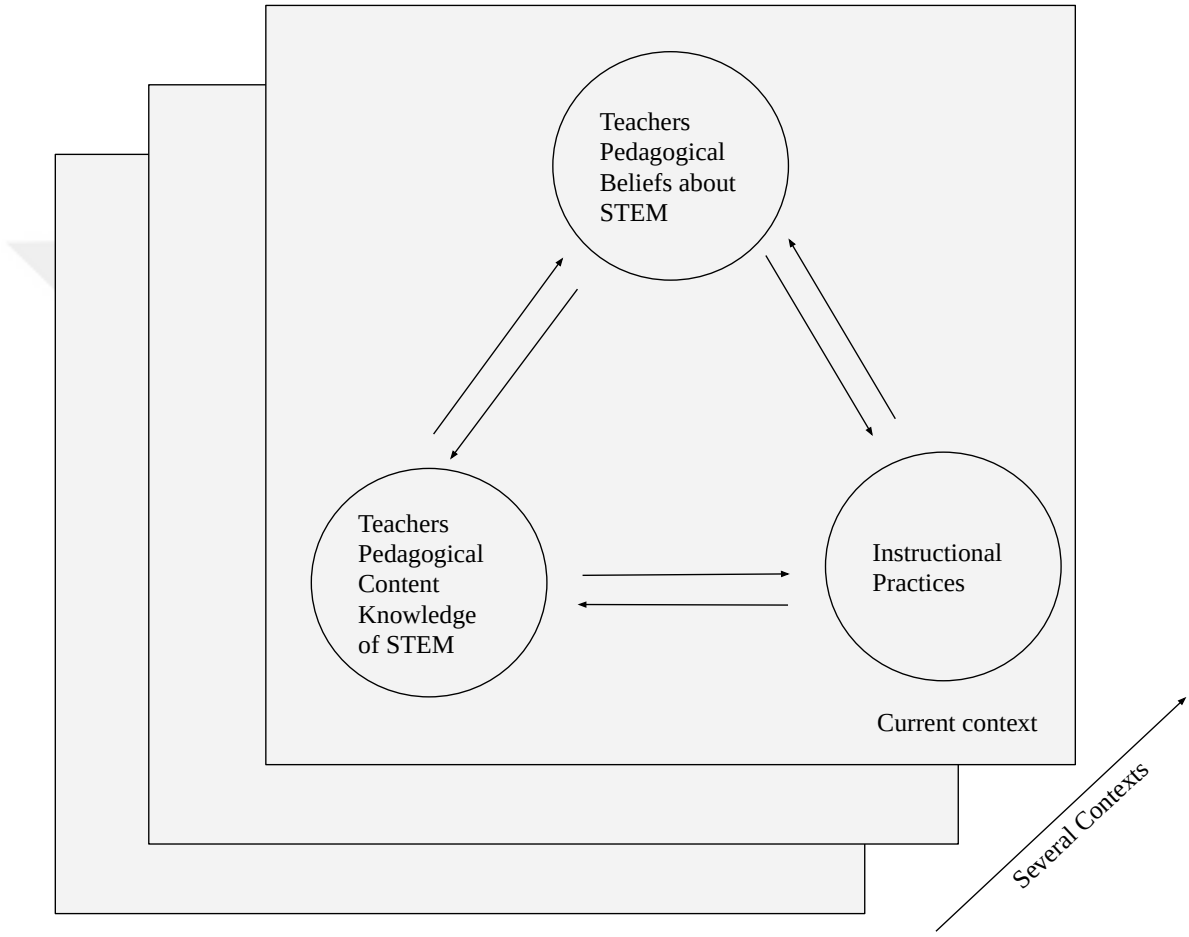

Figure 5.4 Aspects of Teachers STEM Education in Context (Adapted from Schoenfeld, 1998; Scrinzi, 2011)

6. CONCLUSION

The teachers play an active role in students' learning outcomes and attitudes in primary school. Therefore, qualified teachers are needed to foster and support successful students in STEM fields. One of the most effective ways to increase the qualifications of teachers is to ensure their participation in professional development programs. In this study, the influence of a professional development program prepared for integrated STEM education on teachers' pedagogical beliefs, pedagogical content knowledge and practices was investigated.

The literature review on teachers' cognition and practices in integrated STEM education mostly has covered one of the concepts regarding to teacher: PCK, PB and practices. We have obtained comprehensive results by examining teachers' PCK, beliefs, practices and the connections between them. The findings of the study demonstrates that teachers can improve their professional growth if they are provided with supportive environments. Additionally, studies on STEM PCK investigations were generally conducted at the theoretical level. The data of limited experiential studies were based on the statements of teachers. In this study, on the other hand, an in-depth analysis was provided with multiple data sources based on their practices. According to the findings of the research, the pedagogical beliefs and pedagogical content knowledge of teachers about STEM education changed and developed through the professional development course. Consequently, teachers' practices have also changed. This change is due to the professional development created by considering effective PD principles. Moreover, this study discovered the necessity of not excluding the effect of teachers' beliefs about context in teacher beliefs studies. Contextual beliefs also play an important role in the development of teachers' beliefs about learning and teaching and teachers' beliefs about STEM disciplines during the professional development program.

On the other hand, as seen in the STEM PCK framework, the teachers' orientations are related to all sub-elements of STEM PCK. The STEM PCK framework, which was created based on teachers' practices, defines STEM PCK more comprehensively and clearly. It reveals the relationships between its elements more precisely.

During the research process, the changes in teachers' practices were observable in a way that highlighting the student-centered approaches and the emphasizing the connections between disciplines. Findings of the research indicated that this development may be due to

the principles of the professional development program involving (1) conditions of the institution are considered along with goals and interests of the teachers (2) PD allowed teachers to reflect on practice and application, and (3) providing the opportunity for collaborative work. Cognitions of teachers such as pedagogical beliefs and pedagogical content knowledge should be considered in relation to each other and to their practices. A suitable environment should be created for supporting the development of these qualifications in teachers with the effective professional development courses.

7. IMPLICATIONS

The following recommendations were made based on the findings of the research.

7.1. For Teacher Mentors/ Educators

In accordance with the findings of the study, teachers can adopt new beliefs with new experiences and improve their pedagogical content knowledge throughout their profession. According to the data, the change in teachers may be due to some features. The professional development program includes theoretical and practical information. The teachers can adopt the new knowledge because PD is carried out by considering their schools' socio-economic background. A consistent application is implemented by associating new information with the existing knowledge and beliefs of the teachers. PD allows teachers to work collaboratively and to watch best practices in STEM education and discover ways to implement it in their own classes. They plan and develop their own lesson plans together. Teachers are supported throughout the research by providing resources, having meetings after each module, and enable them to reflect critically on their own teaching. Thus, it is recommended that teacher mentors and professional development experts design and implement professional development programs which: (1) observe teachers' knowledge and working conditions, (2) allow teachers to experience and collaborate and receive support in their practices. Additionally, the collaborative approach used in this study is observed to encourage teachers to support each other as learners. The teachers mentioned that the ongoing sharing environment and the ongoing support of the researcher made them feel the support they needed in their own learning processes. According to researchers, teachers' motivations play an important role in their professional development (Banilover et al., 2007; Garet et al., 2001; Supovitz & Turner, 2000). Based on these findings, it is suggested that professional development specialists understand the individual needs and professional development goals of teachers. They should create environments that are built on these, provide cooperation and support teachers. The teachers who develop collaborative skills will begin to explore the conditions for further professional development studies. Furthermore, the teachers can adopt new beliefs with new experiences throughout their profession. In this respect, it is a promising finding for teacher education research. The teachers should be supported to experience innovative approaches with positive experiences. In the process of

applying for professional development courses, efforts should be made for teachers to be in positive environments. Efforts should be toward to complete the professional development course with good feelings, because teachers need emotional and practical support in the process of applying innovative approaches. Thus, teacher educators should provide teachers with positive experiences in the areas targeted for development.

The findings indicate that teachers' orientations towards integrated STEM education can be influential in their educational decisions. Therefore, the professional development specialists should start by understanding the approaches, definitions, and perceptions of teachers about STEM education. They should acquire correct definitions in their professional development programs to enhance teachers' STEM PCKs.

7.2. **For Practitioners**

It has been found out that this development is affected by the conditions although there has been an improvement in the pedagogical beliefs and pedagogical content knowledge of the teachers in integrated STEM education. Therefore, the teachers should contribute to their professional development by cooperating with other teachers who have the same interest and development needs for the benefit of their professional development. Besides, they should cooperate with their colleagues who teach in different conditions. In this way, teachers can contribute positively to constructivist beliefs and STEM PCKs practices by being exposed to environments and good practices that are conducive to the practice of constructivist beliefs.

In the study, according to teachers, they obtained detailed information about students' thinking, reasoning processes, and learning by using formative assessment. Thus, teachers who want to observe the development of their students in more detail in STEM education should apply the formative assessment approach. In this way, they can receive more detailed information about their students.

The teachers had difficulty in finding resources related to the discipline of engineering and technology. The need for quality integrated STEM curriculum and teacher resources has been echoed in many studies. The teachers explained that they could not use some of the resources provided to them because of the language barrier and inadequacy in

their content knowledge. From this point of view, it can be suggested that teachers should do a literature review not only in Turkish, but also in English (Canbaz- Bilicioglu, 2012). They can work collaboratively with the English teachers in their schools on resource review.

7.3. For Educational Researchers

The data show that teachers' STEM pedagogical beliefs, STEM PCKs and STEM practices can change and develop with the professional development program based on theory and practice. However, teachers did not show development in all areas of STEM PCK and STEM pedagogical beliefs. The teachers participated in a 30-hour, 2-week professional development course and implemented STEM modules for a semester. Studies have demonstrated that as the duration of practice increases, permanent changes can be observed in teachers' belief, knowledge, and practices (Osborne et al., 2013; Reiser, 2013). To fully grasp the change in teachers' beliefs, knowledge and practices in integrated STEM education, future research needs to examine the effects of longer studies. Also, the effects of professional development courses on the development of teachers' STEM PCK, STEM PB and STEM practices in a relational and longitudinal manner need to be addressed. Such efforts would provide a much more coherent picture of the development of elementary teachers in the context of integrated STEM education.

Regarding the study, the knowledge, beliefs, and practices of the teachers were intertwined, influencing, and influenced by each other. However, the conditions of the teachers determine which knowledge and beliefs would be reflected in practice. Therefore, teachers' cognitions such as pedagogical content knowledge and pedagogical belief should be considered in relation to each other. STEM education of teachers can be supported more holistically, and it can be understood how it can contribute to a more effective STEM education.

In the current study a STEM PCK framework and STEM PB education framework has been developed based on the current literature and practices in the region was the this study. These frameworks contribute to the current literature. These frameworks have contributed the research in STEM education by highlighting the importance of teachers' orientations toward STEM education in STEM PCK and emphasizing the teachers' beliefs about context in STEM PB. Intrinsically, due to the nature of the case study, this research was aimed to

provide an in-depth analysis of professional development course in a public school. Therefore, it was conducted in a single public school with a small number of participants. The STEM PCK framework and the STEM PB framework need to be tested with teachers from different backgrounds. The region was in a low socio-economic community in an area of Istanbul that receives immigrants from the eastern part of Turkey. These situations may influence teachers' attitudes towards the STEM approach, their priorities, and goals in STEM education. There may be other factors that make teaching easier or more difficult in STEM education applied in different environments. The prominent factors require further research. Factors affecting teachers' STEM education should be investigated with other studies developed in urban areas.

The teachers worded their lack of content knowledge and self-efficacy in integrated STEM education. In future studies, the impact of content knowledge in STEM PCKs and the impact of teachers' self-efficacy beliefs in STEM PBs should be analyzed. Further studies could illustrate that a specific relationship between the content knowledge, self-efficacy beliefs, STEM PCK and STEM PB might affect the success of teachers in their integrated STEM practices.

Finally, this research has not investigated how teachers' STEM PCKs and STEM PBs influence students' learning outcomes. However, according to teachers report, the motivation of students to learn in science and mathematics disciplines and the participation have increased during the STEM modules. Their 21st century skills have improved. Their attitudes towards science and mathematics lessons have changed positively. In future studies, it is recommended to analyze the effect of professional development courses applied to improve STEM education on students' learning.

7.4. **For Teacher Educators**

According to the data, teachers' learning experiences in engineering and technology disciplines are very limited. And their limited experiences are formed by their own efforts. They did not receive any formal education in these disciplines during their pre-service education. Considering that university education is planned centrally, this is a common problem of all teacher training institutions in Turkey. Moreover, the teachers have misconceptions about these disciplines. The lack of resources for these disciplines comes

forward while creating STEM modules. Their course designs did not contain content that allowing students to learn in-depth in STEM disciplines. The findings of this study are in line with those of studies exhibiting the lack of content knowledge of elementary teachers in technology and engineering disciplines. The results offer that teacher training institutions should reshape their curricula to include courses to improve STEM education. It is recommended that teacher education programs should take steps to ensure all teachers candidates upgrade their content knowledge in STEM disciplines, pedagogical content knowledge.

The analysis of the teachers' beliefs show that the teachers had negative attitudes towards science and mathematics disciplines. This might be because they are involved in traditional learning experiences during their K-12 education. Therefore, pre-service teachers should be taught with a constructivist approach rather than a plain lecture during their university education. If they are taught with the constructivist method, pre-service teachers will have the opportunity to discover knowledge, learn by collaborating, and learn conceptually, so that they can develop a positive attitude towards STEM disciplines and reflect this in their teaching. According to the studies, teachers concentrate on to the subjects in which they develop a positive attitude. They spend more time on these subjects' teaching and can better support students' learning in these disciplines (Siew et al., 2015; Weber et al., 2013).

The teachers' teaching methods were generally teacher centered. Their subject-specific strategies were very limited. In addition, the teachers were not able to develop themselves sufficiently in knowledge of student during their education at the university. They often use the representations and models presented to them during their K-12 education. Accordingly, education faculties should consider to focuses on pedagogical content knowledge in teaching courses. Thus, teachers can design and implement lessons that will enable students to develop conceptual learning.

Finally, the teachers stated that their university education did not equip them to teach in all regions Turkey since there are substantial differences between regions regarding their socio-cultural, socioeconomic status. Although the participants of this study were limited to 3 people, each of the participating teachers received university education in a different region

of Turkey. And they had teaching experience in different regions. Therefore, the results can give us a snapshot. It is recommended that teacher training institutions should be provided a curriculum that will appeal to students from different regions of the country.

7.5. For Ministry of Education

The Turkish education system is effective in the beliefs and practices of teachers regarding STEM education. In this study, the teachers designed and implemented their own STEM modules during the professional development program. The study clarifies the negative impacts of Turkish educational system on teachers' innovative practices. Teachers report the low level of autonomy in determining the curriculum and flexibility of defining learning practices. Teachers stated their willingness to support their students' achievement in STEM subjects. However, since the placement exams are very competitive, the extent to which examinations were narrowing the curriculum taught in their classes. Therefore, the teaching style (traditional, rote-based) and subjects (emphasis on only the subjects that come out in the exam) limit their integrated STEM-based designs. Additively, the specific course and break times applied throughout the school and the compulsory provision of the resources to be used by the Ministry of Education make it difficult for them to implement project-based STEM approaches. Thus, it is recommended that the Ministry of Education grant autonomy to teachers in their curriculum implementation. In addition, the freedom to process the subjects in the curriculum in the order and time should be determined according to the interests and needs of the students. The level of freedom may increase the efficiency of the teachers in STEM education. A reflection of educational reforms in developed countries by making use of innovative curricula emerging as the ability to adapt existing learning outcomes to teaching can positively affect teachers' productivity in STEM education. Besides, allowing teachers the freedom to organize their lesson hours in such a way that they can apply innovative STEM pedagogies such as project-based, problem-based or modeling can raise the productivity of teachers in STEM education. Thus, teachers should be given autonomy in the process of applying the curriculum.

In this study, it was aimed to enhance teachers' knowledge and skills in practicing STEM education by using the best practice videos. By examining these videos together, they adapted the teaching methods and techniques they examined. However, all the resources

used in this research were recorded in English language and generally as the output of the projects conducted in the USA. The teachers obtained and benefited from explicit information about different elements of teaching such as classroom management, teaching strategies, assessment, and evaluation. Therefore, it is suggested that the Ministry of Education can create a video-case bank consisting of best practice examples for teachers. It is also offered to translate the videos into Turkish and make them ready for the use of educators.

Finally, the teachers think that the professional development of public-school teachers is not valued enough. The fact that there is no difference between teachers who contributed to their professional development and who did not contribute to their professional development at all caused deficiency in their motivation over time. Therefore, it is recommended that teachers' professional development should be encouraged by the Ministry of Education.

APPENDICIES

APPENDIX A

SAMPLE WEEKLY SCHEDULE

3rd Grade Weekly Schedule				
Monday	Tuesday	Wednesday	Thursday	Friday
Life Science	Science	Elective Course	Science	Life Science
Turkish	Turkish	Science	Turkish	Turkish
Turkish	Turkish	Science	Turkish	Turkish
Mathematics	Mathematics	Mathematics	Mathematics	Mathematics
Recess				
Music	English	English		
Physical Education and Play	Physical Education and Play	Physical Education and Play	Physical Education and Play	Physical Education and Play

APPENDIX B

Reflection Paper Guide

Öğretmen Yansıtma Günlüğü

Ad ve Soyadınız:	**Dersin İşlenme Tarihi:**
Sınıf:	

1) Ders Öncesi Planınız (Ders öncesindeki planlama sürecinizi kısaca anlatınız.)

2) Ders Sonrası İlk Düşünceler: Ne güzel gitti? (Dersin bitiminde nasıl hissettiğinizi neler düşündüğünüzü paylaşınız. Planlarınıza uyabildiniz mi? Planlamadığınız öğrenme fırsatları ortaya çıktı mı?)

3) Ne fark ettiniz? (Bu dersi planlamanızdan başlayarak işlemenize kadar geçen süreçte neleri fark ettiniz?)

4) Öğrencilerin öğrenmeleriyle ilgili ne düşünüyorsunuz? (Neleri öğrendiler? Buna bakarak bir sonraki derste ne öğrenmelerini bekliyorsunuz?)

5) Bu dersle ilgili bir şeyi değiştirmek isteseydiniz neyi değiştirirdiniz?

6) Zorlandığınız bir durum oldu mu? Olduysa tanımlar mısınız?

APPENDIX C

Interview Protocol

Öğretmen Görüşme Protokolü

Tarih: _____ Başlama Zamanı: _____ Bitiş Zamanı: _____

Açıklama:
Bu araştırmaya katıldığın için teşekkürler. Bu araştırmadan elde edilen bilgilerin diğer eğitimciler, yöneticiler ve STEM egitimini sınıflarında ve okullarında uygulamak isteyen diğer eğitim paydaşlarına yararlı olacağı umulmaktadır. Bu görüşme yaklaşık 1,5 saat sürmektedir ve kaydedilmektedir. Kayıt sona erdiğinde trankstriptleri görebilirsin. Başlamadan önce sormak istediğin bir soru var mı?

1. Şubat tatili süresince katıldığın kursu anlatır mısın?
2. Katılma motivasyonun neydi?
3. Bu kursta öğrendiğin en önemli üç şeyi anlatır mısın?
4. Kurs bittiğinde neler hissettiğini anlatır mısın?
5. STEM eğitimini nasıl tanımlıyorsun?
   Sence geleneksel öğretimden farkları neler?
6. STEM eğitimindeki disiplinler arasındaki ilişkiyi nasıl görüyorsun?

   Matematik'in rolu ne?
   Fen'in rolu ne?
   Teknoloji'nin rolü ne?
   Mühendislik'in rolü ne?

7. STEM eğitimini sınıfında uyguluyor musun?
8. STEM eğitimi senin ders vermeni ya da dersin içeriklerini anlatmanı nasıl etkiliyor?
   Sınıftaki rolünün değiştiğini düşünüyor musun?
9. STEM eğitiminin sınıfında yarattığı olumlu etkileri anlatabilir misin?
10. Öğrencilerinin STEM eğitimi ile ders verdiğinde neler kazandığını düşünüyorsun?
11. Öğrencilerinin edindiği bu beceriler senin bundan sonraki ders planlarını ya da gelecekte öğretmeyi planladığın konuları etkiliyor mu?
12. Bana STEM eğitimi ile ilgili tüm deneyimlerini anlatır mısın?
13. Sence STEM eğitimini kullanmanın artıları, olumlu yanları neler?
14. Sence STEM eğitimini kullanmanın eksileri, olumsuz yanları neler?
15. STEM eğitimi yaptığında öğrencilerin öğrenmelerini nasıl ölçüyorsun?
16. Deneyimlerinden yola çıkarak STEM'i sınıfında kullanmak ister misin? Neden?
17. Eklemek istediğin herhangi bir şey var mı?

APPENDIX D

Lesson Plan Template

<table>
<tr><td colspan="3">Ders Planı</td></tr>
<tr><td>Tarih</td><td colspan="2">Öğretmen Adı:</td></tr>
<tr><td>Süre</td><td></td><td>Ders Sayısı:</td></tr>
<tr><td colspan="3">Mantıksal Temel: Bu ders öğrencilerinin şu anki düşünmesiyle nasıl bağlantılı?</td></tr>
<tr><td colspan="3">Önemli Beceriler (Kazanımlar):
Öğrencilerin ne yapabiliyor ya da neyi gösterebiliyor olmalı?</td></tr>
<tr><td colspan="3">Süreç(Uygulama Planı):
<table><tr><td>Öğrenmeyi nasıl sağlayacaksın?</td><td>Öğrencilerin ne yapacak?</td></tr><tr><td></td><td></td></tr></table></td></tr>
<tr><td colspan="3">Anahtar Sorular ya da Diğer Stratejiler:
Senin anlattığın kavramı/konuyu anladıklarından emin olmak için ne soracaksın?</td></tr>
<tr><td colspan="3">Farklılaştırma/Değişiklikler:

Öğrencilerinin öğrenme ihtiyacını karşılamak için nasıl etkinlikler kullanacaksın? B planın ne?</td></tr>
<tr><td colspan="3">Kaynaklar:
Kullanacağın eğitsel materyaller ve gerekli teknolojiyi açıkla.</td></tr>
<tr><td colspan="3">Yansıtma / Kapanış:
Ne iyi gitti? Neyi değişik yapardın? Bu bilgiyi bir sonraki plan hazırlama sürecinde nasıl kullanacaksın?</td></tr>
</table>

APPENDIX E

A Section from Professional Development Course

1. Gün: Birbirimizi tanıma

İstasyon 1 – Birbirimiz hakkında öğrenme ve paylaşma (20 dakika)

Kişisel ve profesyonel geçmişin hakkında bir yazı yazar mısın? Çocukluğun, yaşadığın çevre(ler), öğretmen olma sürecin, üniversite eğitimin hakkında bilgileri de ekleyebilir misin? Öğretmenlik deneyimlerini de anlatır mısın?

Bir kişiyle eşleşip aşağıdaki soruları birbirinize sorun. Daha sonra karşınızdaki kişi hakkında edindiğiniz bilgileri not alın. Yeni sorular ekleyebilirsiniz.Aldığınız notlardan yola çıkarak, grup arkadaşınız hakkında öğrendiklerinizi tüm grupla paylaşın.

1. Nerede büyüdün? Sen öğrenciyken okul deneyimlerin nasıldı?
2. Öğretmen olmana sebep olan şey neydi?
3. Eğitim fakültesi programın hakkında bilgi verir misin? Nerede tamamladın? Öğretmen olmana nasıl yardımcı oldu?
4. Nerelerde öğretmenlik yaptın? Hangi benzerlik ve farklılıkların öne çıktığını düşünüyorsun farklı yerlerde öğretirken? Gerçek hayatta öğretmenlik ve eğitim fakültesinde hazırlandığın öğretmenlik arasında nasıl bir farklılık var?
5. En çok ne zaman başarılı olduğunu hissettin? 'Başarı'yı nasıl tanımlıyorsun?
6. En çok nelerde zorlandın? Bu zorlukların sana nasıl katkıları olduğunu düşünüyorsun?

(30 dakika) Grup arkadaşınla ilgili neler öğrendiğini paylaş ve arkadaşını bize tanıt.

İstasyon 2 – Teoriden Pratiğe (30 dakika)

Bir grup arkadaşı ile çalış ve aslında içinden gelen, yapmayı hep istediğin, idealinde olan Matematik ve Fen öğretim biçimini tanımla. (Mesela müfredat, günlük uygulamalar, sınıf yönetimi, pedagojik yaklaşımlar, vs) Bir de şu anki sınıfında var olan öğretimi tanımla. Bu aradaki farkı göz önüne alarak, sizce ideal fikirler nereden geliyor (deneyim, eğitim fakültesi, mesleki gelişim kursları) Üzerinde düşünmek üzere 3 durum belirle.

1. Bu durumların kaynağı ne?
2. Bu sorunların üzerinden gelme hakkında ne düşünüyorsun, nasıl hissediyorsun?
3. Bu sorunları tanımlayan bir görsel geliyor mu aklına?

Grup arkadaşınla birlikte bu durumları içeren bir görsel çiz. Daha sonra tüm arkadaşlarınla paylaş.

APPENDIX F

Mathematics and Science Autobiography

Matematik ve Fen Otobiyografisi

Bu etkinlikle Matematik ve Fen öğrenme sürecinle ilgili bilgi almak istiyorum. Aşağıdaki soruların tamamını yanıtlamaya çalışarak matematik otobiyografini yazar mısınız? Bu soruların sistematik olarak cevaplanması gerekmiyor. Bu soruları sizin hakkınızda daha çok bilgi vermesi için bir rehber olarak düşünebilirsiniz. Matematik ve Fen deneyimlerin hakkında önemli olduğunu düşündüğünüz her şeyi detaylı bir şekilde yazabilirsiniz. Bu otobiyografide özellikle ilkokuldan günümüze kadar matematik ve fen ile ilgili tüm deneyimlerini yazmalısınız.

(Matematik ve Fen deneyimi ile geçmişten günümüze kadar sizin Matematik ve Fen becerilerini etkileyebilecek her şeyden bahsediliyor. Mesela, öğrenme deneyimlerin, öğretmenlerin, ailenin etkisi, medya)

Yaklaşık iki sayfa sürecek bu otobiyografiyi grup arkadaşınızla paylaşın. İsminizi eklemeniz gerekmiyor. Burada amacımız genel olarak birbirimizin matematik ve fen deneyimleri ile ilgili neler öğrendiğimizi görmek ve nasıl sorular üzerinde düşünmeye başladığımızı belirlemek.

1. İlköğretimde öğrenciyken nasıl bir matematik ve fen öğretimi gördüğünü hatırlıyor musunuz? Nasıldı? Neler ön plana çıkıyor?
2. Olumlu bir matematik/fen anın hakkında düşünür müsünüz? Nasıl hissettiniz? Başarılı mıydınız? Başarılı olmanıza ne katkı sağlamıştı?
3. Olumsuz bir matematik/fen anın hakkında düşünür müsünüz? Neler oldu? Nasıl hissettiniz? Buna ne yol açtı hatırlıyor musunuz?
4. Matematik/fen hakkında düşündüğünüzde aklına gelen ilk 3 kelime nedir? Neden bunları düşündüğünüzü açıklar mısın?
5. Matematikte/fen bilgisinde grup çalışmasına katıldınız mı? Nasıldı? Bireysel olmasından farklı yönleri var mıydı? Nasıl farklıydı?
6. Matematikte/fen bilgisinde başarılı olmanızı sağlayan bazı yöntemler nelerdi?
7. Sizi matematikte/fen bilgisinde başarılı olmaktan alıkoyan güçlükler nelerdi?
8. Başka birine matematik/fen bilgisi hakkında yardımcı oldunuz mu? Hangi konuda ona yardım ettiniz?
9. Hiç fazladan destek aldınız mı Matematikle/Fen bilgisi ilgili? Yardımcı oldu mu?
10. Matematik/fen öğreniminle ilişkisi olduğunu düşündüğünüz bireysel bir özelliğin var mı? (cinsiyet, dil, gelir düzeyi)

Kendinizin ve arkadaşlarınızın otobiyografisini okuduktan/birbirinizden dinledikten sonra, aşağıdaki T- tablosunu tüm grupla doldurunuz ve tüm grupla tartışınız.

Sizce öğrencilerinizin Fen/ Matematik kimlikleri NE ZAMAN gelişmeye başlıyor?	Sizce öğrencilerinizin Fen/ Matematik becerileri NASIL gelişiyor?

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