DESIGN AND IMPLEMENTATION OF A GRADUATE COURSE FOR DEVELOPMENT OF TECHNOLOGICAL PEDAGOGICAL CONTENT KNOWLEDGE

A THESIS SUBMITTED TO
THE GRADUATE SCHOOL OF SOCIAL SCIENCES
OF
MIDDLE EAST TECHNICAL UNIVERSITY

BY

GAMZE ÇETİNKAYA AYDIN

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR
THE DEGREE OF DOCTOR OF PHILOSOPHY
IN
THE DEPARTMENT OF ELEMENTARY EDUCATION

SEPTEMBER 2022

Approval of the thesis:

DESIGN AND IMPLEMENTATION OF A GRADUATE COURSE FOR DEVELOPMENT OF TECHNOLOGICAL PEDAGOGICAL CONTENT KNOWLEDGE

submitted by **GAMZE ÇETİNKAYA AYDIN** in partial fulfillment of the requirements for the degree of **Doctor of Philosophy in Elementary Education, the Graduate School of Social Sciences of Middle East Technical University** by,

Prof. Dr. Sadettin Kirazcı
Dean
Graduate School of Social Sciences ____________________

Prof. Dr. Semra SUNGUR
Head of Department
Department of Elementary Education ____________________

Prof. Dr. Jale ÇAKIROĞLU
Supervisor
Department of Mathematics and Science Education ____________________

Examining Committee Members:

Prof. Dr. Özgül YILMAZ TÜZÜN (Head of the Examining Committee)
Middle East Technical University
Department of Mathematics and Science Education ____________________

Prof. Dr. Jale ÇAKIROĞLU (Supervisor)
Middle East Technical University
Department of Mathematics and Science Education ____________________

Prof. Dr. Yezdan BOZ
Middle East Technical University
Department of Mathematics and Science Education ____________________

Prof. Dr. Işıl KABAKÇI YURDAKUL
Anadolu University
Department of Computer Education and Inst. Tech. ____________________

Assoc. Prof. Dr. Sedef CANBAZOĞLU BİLİCİ
Gazi University
Department of Mathematics and Science Education ____________________

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

Name, Last Name: Gamze ÇETİNKAYA AYDIN

Signature:

ABSTRACT

DESIGN AND IMPLEMENTATION OF A GRADUATE COURSE FOR DEVELOPMENT OF TECHNOLOGICAL PEDAGOGICAL CONTENT KNOWLEDGE

ÇETİNKAYA AYDIN, Gamze
Ph.D., The Department of Elementary Education
Supervisor: Prof. Dr. Jale ÇAKIROĞLU

September 2022, 245 pages

Following a design-based research approach, the present study aimed to develop a course design named Theory – Application – Practice (T-A-P) and investigate its effectiveness for graduate level students' development of technological pedagogical content knowledge (TPACK). Participants' views on the T-A-P course design, the change in their perceived competencies and self-efficacy of TPACK, and the change in their TPACK level were investigated to test the effectiveness of the course design. The proposed design was implemented in two iterative cycles with a total of 12 graduate level students pursuing a M.S. or Ph.D. degree in elementary science education. To examine participants' views about course design, data were collected by means of written feedback and interviews. Thematic analysis was used to analyze data, and the findings revealed that participants found the T-A-P course design helpful for their TPACK development. Participants' perceived competencies and self-efficacy of TPACK were measured by pre- and post-administration of two TPACK scales, and Wilcoxon Signed Rank Tests were performed to investigate whether the change was statistically significant. The results revealed significant improvements in participants' scores for both of the scales in both cycles of implementation. Lastly, lesson plans, micro-teachings and interviews were used to capture the development of participants' levels of TPACK. It was seen that after attending a graduate course based on T-A-P course design, participants' level of TPACK progressed at different levels in both cycles of implementation. T-A-P course design, developed based on the related literature, was found to be effective for promoting graduate level students' TPACK development.

Keywords: Technological Pedagogical Content Knowledge, Course Design, Design-Based Research, Science Education, Technology Integration

ÖZ

TEKNOLOJİK PEDAGOJİK ALAN BİLGİSİNİN GELİŞTİRİLMESİNE YÖNELİK BİR YÜKSEKÖĞRETİM DERSİNİN TASARIMI VE UYGULANMASI

ÇETİNKAYA AYDIN, Gamze
Doktora, İlköğretim Bölümü
Tez Yöneticisi: Prof. Dr. Jale ÇAKIROĞLU

Eylül 2022, 245 sayfa

Bu çalışmanın amacı, tasarım tabanlı araştırma yöntemini kullanarak, Teori – Alıştırma – Pratik (T-A-P) adlı bir ders tasarımı geliştirmek ve bu tasarımın lisansüstü düzeydeki öğrencilerin teknolojik pedagojik alan bilgisini (TPAB) geliştirmedeki etkililiğini değerlendirmektir. T-A-P ders tasarımının etkililiğini değerlendirmek için katılımcıların ders tasarımı hakkındaki görüşleri, TPAB yeterlik algıları ve öz yeterlik inançlarındaki değişim ve TPAB düzeylerindeki değişim araştırılmıştır. Önerilen ders tasarımı, yüksek lisans veya doktora düzeyindeki toplam 12 fen eğitimi öğrencisiyle iki ardışık dönem boyunca uygulanmıştır. Katılımcıların ders tasarımı hakkındaki görüşlerini incelemek için yazılı geri bildirimler ve görüşmeler yoluyla veri toplanmıştır. Tematik analiz kullanılarak analiz edilen verilerin sonucunda, katılımcıların T-A-P ders tasarımını TPAB gelişimleri açısından faydalı buldukları anlaşılmıştır. Katılımcıların TPAB yeterlik algıları ve öz yeterlik düzeylerindeki değişim, iki TPAB ölçeğinin ön-test ve son-test olarak uygulanmasıyla ölçülmüş ve değişimin istatistiksel olarak anlamlı olup olmadığını değerlendirmek için Wilcoxon

İşaretli Sıralar Testleri yapılmıştır. Sonuçlar, iki uygulama döngüsünde de katılımcıların her iki ölçekten elde ettikleri puanlarda önemli gelişmeler olduğunu ortaya koymuştur. Son olarak, katılımcıların TPAB düzeyindeki gelişimi incelemek için ders planları, mikro-öğretimler ve görüşmeler kullanılmıştır. T-A-P ders tasarımına dayalı bir lisansüstü derse katıldıktan sonra, katılımcıların TPAB düzeylerinin her iki uygulama döngüsünde de farklı düzeylerde ilerlediği görülmüştür. Sonuç olarak, ilgili alan yazına dayalı olarak geliştirilen T-A-P ders tasarımının lisansüstü düzeydeki fen eğitimi öğrencilerinin TPAB gelişimini desteklemede etkili olduğu görülmüştür.

Anahtar Kelimeler: Teknolojik Pedagojik Alan Bilgisi, Ders Tasarımı, Tasarım Tabanlı Araştırma, Fen Eğitimi, Teknoloji Entegrasyonu

To my dear husband İzzet Aydın
for his endless love, support and understanding.

"No matter what happens, I am always proud of you."

ACKNOWLEDGEMENTS

I would like to thank my supervisor, mentor, teacher and biggest motivator Prof. Dr. Jale Çakıroğlu for her valuable guidance, encouragement, and support. Since my undergraduate education at METU, she has always been a great role model for me and many others. She is the best supervisor a graduate student can ask for, and I feel so lucky to have her by my side during this process. Besides her academic qualities, she is one of the kindest, nicest, and most genuine person I have ever met. Thank you sincerely for always being there for me.

I would like to thank my committee members Prof. Dr. Özgül Yılmaz Tüzün, Prof. Dr. Yezdan Boz, Prof. Dr. Işıl Kabakçı Yurdakul, and Assoc. Prof. Dr. Sedef Canbazoğlu Bilici for their valuable feedback, guidance, and suggestions. It was a privilege to get feedback from you to improve this dissertation.

I would like to thank all of the amazing professors, research assistants, and personnel I had the chance to work with at METU. I have gained many lifelong friends while working there. It was a great experience to work with you, learn from you, and feel your support.

I would like to thank my family Nebile, Galip, and Gökhan Çetinkaya. Without your endless love and support, I would not have achieved anything in my life. I also would like to thank my second family Hülya, Tutku, Nehir, and Mehmet Öztürk. I am deeply grateful to have you in my life.

I would like to thank my wonderful husband, İzzet Aydın. Your unconditional love and support make me feel very special. Marrying you is the best decision I have ever made.

Lastly, I would like to thank the Scientific and Technological Research Council of Turkey (TÜBİTAK) for their financial support during my graduate education.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

TPACK	: Technological Pedagogical Content Knowledge
T-A-P	: Theory-Application-Practice
PCK	: Pedagogical Content Knowledge
ICT	: Information and Communication Technologies
LMS	: Learning management system
DBR	: Design-based research

CHAPTER 1

INTRODUCTION

The fourth industrial revolution, also known as the digital revolution, has radically altered all aspects of our lives. Today, most of our daily routines depend on modern digital technologies. This transformation does not exclude schools; technological tools such as smart boards, computers, tablets, and online systems have become widely used in classrooms all around the world.

Digital technologies have become more accessible and available in schools, and therefore, the use of technological tools in classrooms has increased significantly in recent years. However, the frequent use of technological tools does not necessarily mean that the integration of technology is successful (Farjon et al., 2019). Researchers have recognized that the presence of technology does not guarantee its effective use in promoting students' learning, and the focus shifted to meaningful integration of technology into teaching (Graham et al., 2009).

For technology to make a significant difference in education, teachers are expected to use technology effectively in a way that enhances student learning. Without teachers with the right pedagogical skills to integrate technology in a way that improves student learning, technology cannot meet its educational promise (Keengwe & Onchwari, 2011). Therefore, for meaningful and successful integration of technology into education, teachers need to gain the required skills for their new role as a guide to facilitate students’ thinking by using the right combination of technology, pedagogy, and content.

However, learning how to teach with technological tools in an effective way is a complex task for teachers; it requires not only knowing technological tools but also how to use these tools to design powerful learning activities (Valanides, 2018). Even though several models have been proposed in the last few decades to explore technology integration into education, most of them were generally focused on the technological skills of teachers, ignoring the pedagogical aspects of teaching with technology (Jimoyiannis, 2008).

For this reason, different frameworks for technological pedagogical content knowledge (TPACK) (e.g., Angeli & Valanides, 2005; Mishra & Koehler, 2006; Niess, 2005) were introduced to propose a conceptual framework for effective teaching with technology considering the interactions between technology knowledge, pedagogical knowledge, and content knowledge. Especially the framework by Mishra and Koehler (2006) has become widely popular and used in numerous studies. In this framework, knowledge of content, pedagogy, and technology are not isolated bodies of knowledge; they are all interrelated and form teachers' main knowledge. Teachers need to combine content, pedagogy, and technology in a meaningful way by considering contextual factors. Niess (2008, p. 224) described TPACK as

> a way of thinking strategically while involved in planning, organizing, critiquing, and abstracting, for specific content, specific student needs, and specific classroom situations while concurrently considering the multitude of 21^{st} century technologies with the potential for supporting student learning.

Knowledge of content, pedagogy, and technology work together to form knowledge of where to use technology, which technology to use, and how to teach with technology (McCrory, 2008). Researchers have tried to find best practices for technology integration into education by using the TPACK framework to be able to improve the quality of school instruction and teacher education (Voithofer & Nelson, 2021).

Teachers have a key role in the technology integration process because the integration of technology into teaching is not just a different way of presenting information; technology, pedagogy, and content should be combined in such a way that students become active learners engaged in appropriate learning activities. Teachers need to know how to use technology as a tool for improving the learning process, not a tool to carry out direct instruction with reading materials presented via technological tools

(Jimoyiannis, 2010). The quality and effectiveness of technology integration into education highly depend on the teacher.

Unfortunately, research consistently showed that beginning teachers do not feel ready to use technology effectively in their classrooms; there is a gap between teacher education programs and actual classroom practices (Gao et al., 2011; Tondeur et al., 2017). Teachers do not enter the teaching profession with required skills for effective technology integration. Research shows that graduates of teacher education programs do not feel prepared to use technology to improve student learning (Kaplon-Schilis & Lyublinskaya, 2020; Ottenbreit-Leftwich et al., 2010). For this reason, reforming teacher education programs to raise teachers with high levels of TPACK (Mouza, 2016) and designing professional development programs to increase in-service teachers' TPACK (Baran et al., 2016) have been important research areas to increase the quality of technology integration in schools.

Improving teacher education programs to prepare teachers to use technology in their future classrooms effectively has become a challenge for teacher educators. For teacher education programs, Beck and Wynn (1998) described a continuum; at one end, technology is presented as a separate course, whereas on the other end, technology integration is used and emphasized within the entire program. Unfortunately, most of the teacher education programs are closer to the first end of that continuum (Niess, 2005). In order to move higher education to the other end, some universities designed and implemented professional development programs related to technology integration. However, as Stover and Veres (2013) pointed out, these professional development programs were generally focused on technology, ignoring its relationships with content and pedagogy.

Niess (2005) stated that it is not enough to integrate technology in teacher education programs because teachers do not necessarily teach the way they were taught; teacher education programs need to teach how to teach with technology. If teachers are expected to teach with technology effectively, they should be provided with explicit instruction and effective practices of technology integration during their education. As

Chai et al. (2010) argued, just offering technology courses in teacher education programs is not enough for TPACK development. Teacher education programs need to teach content knowledge, pedagogical knowledge, and technological knowledge in relation to each other. TPACK framework-based courses may help teachers to develop the required knowledge and skills for effective technology integration (Tondeur et al., 2017).

The same principle applies to the professional development programs aiming to develop in-service teachers' TPACK. Professional development programs should include experiences designed to help teachers understand the relationship between technology and context, develop technological skills, and practice the application of new technologies in their subject area (Figg & Jaipal-Jamani, 2014). Learning about theories of technology integration (Baran & Uygun, 2016; Lee & Kim, 2014; Tondeur et al., 2012), examination of technology-integrated learning materials (Baran & Uygun, 2016; Mouza et al., 2014), examination of different technologies and identifying their educational affordances, limitations, and uses (Angeli & Valanides, 2009; 2013); engagement in design activities (Baran & Uygun, 2016; Koehler et al., 2005; Lee & Kim, 2014; Voogt et al., 2016), implementing technology-enhanced lesson plans (Baran & Uygun, 2016; Lee & Kim, 2014), and providing feedback about teacher designs (Tondeur et al., 2012; Lee & Kim, 2014) are suggested as effective strategies to promote TPACK development of teachers.

In addition, researchers argue that the knowledge required for effective technology integration by teachers varies according to the discipline they teach; effective integration of technology may look different for science classrooms and social studies classrooms (Graham et al., 2009). For this reason, it is important to design interventions according to the subject area to be taught. Based on the previous studies conducted to improve science teachers' TPACK, science teachers need continuous feedback and support, guidance, active involvement, and authentic learning experiences to be able to integrate technology into instruction effectively (Jang & Chen, 2009; Jimoyiannis, 2010).

Within the science education research community, various researchers have argued that technology has a significant potential to improve science instruction, students' involvement in science lessons, and students' understanding of scientific concepts (Bell et al., 2013). Integration of technologies might improve science teaching and learning by making it easier to display abstract concepts through graphical representations, animations, videos etc., by representing natural events very slowly or fast on a big or small scale for students to observe, and by summarizing the results of experiments to draw conclusions (Grimalt-Álvaro et al., 2019).

Moreover, efficient technology integration has the potential to promote conceptual understanding of scientific concepts (Wu & Huang, 2007). Effective use of technological tools might also help students engage in scientific inquiry, construct their own knowledge, work as scientists, and improve their problem solving skills (Guzey, & Roehrig, 2009; Trowbridge et al., 2008). In addition, technological tools might facilitate teachers' implementation of inquiry practices with the help of simulations, digital media, modeling tools, data analysis and interpretation programs, and visualization opportunities (Bell et al., 2013; Bell & Trundle, 2008; Lee et al., 2010; Schnittka & Bell, 2009; Varma et al., 2008; Wu & Huang, 2007). There are many available technologies ranging from simple to complex that might be used to improve science instruction.

Considering the possible improvements technology can bring into science education, effective integration of technology into classroom practices can improve the quality of science teaching and learning. Technology has a significant potential to improve science instruction, and the level and the quality of its integration highly depend on science teachers. For this reason, finding effective practices to develop science teachers' TPACK is very important.

1.1. Statement of the Purpose and Research Questions

The main purpose of the present study was to develop a course design to be implemented in *Teaching Science with Technology* graduate course and investigate its influence on graduate science education students' TPACK. For this reason, the relevant literature was reviewed to identify important characteristics of successful models for developing teachers' TPACK (see 2.2.2. Models for TPACK Development of Teachers). Then, a course design named as *Theory-Application-Practice (T-A-P)* was designed. The principles guided the course design are explained in *Section 2.2.3 Principles of the (T-A-P) Course Design*.

The proposed design was implemented in two iterative cycles. To investigate its effectiveness for TPACK development of graduate science education students, the following research questions were answered:

1. What were graduate science education students' views about *Teaching Science with Technology* course based on T-A-P course design?
2. Is there a change in graduate science education students' perceived competencies and self-efficacy of TPACK after attending the *Teaching Science with Technology* course based on T-A-P course design?
3. How did graduate science education students' level of TPACK change as they attended the *Teaching Science with Technology* course based on T-A-P course design?

1.2. Significance of the Study

In order to achieve effective technology integration in schools, teachers should possess a high level of TPACK. Frequent technology use in the classroom does not necessarily improve student outcomes; to improve classroom instruction and student outcomes, teachers need support to integrate technology effectively (Zinger et al., 2017). However, there is no perfect way of improving teachers' TPACK. Preparing teachers for technology integration in their classroom practices is a challenging, complex process (Liu, 2016; Tondeur et al., 2012).

One of the biggest advantages of the design research is that it tries to develop solutions to real teaching and learning problems in collaboration with practitioners and researchers; it is not isolated from practice (Reeves, 2006). Following design-based research methodology, this study aims to make a significant contribution to the solution of the problem of determining effective practices for TPACK development of teachers.

The most important significance of the present study is its contribution to the efforts of developing science teachers' TPACK. The present study proposes a course design for the development of technological pedagogical content knowledge and aims to make a significant contribution to the practice of science teacher education instead of describing an existing situation. Determining the effective strategies for developing science teachers' TPACK is an important concern for science education, and this study aims to make a significant contribution by proposing a practical solution that can be implemented and adapted to various contexts.

The identification of principles that could be employed to design effective instructional design models to improve TPACK is important. Purposefully selecting and combining the strategies for teachers' TPACK development and testing their influence is important to be able to match teachers' needs to development strategies (Harris, 2016). Although the TPACK framework has been studied widely, and researchers agree that TPACK is needed for effective technology integration, there is still a need for clarification to guide future educational efforts to prepare teachers (Brantley & Ertmer, 2013). The findings of the study can be useful and guiding for future studies aiming to determine and use principles for designing effective programs for teachers' TPACK development. By combining different strategies based on the literature, organizing them into a course design, creating course content according to these principles, and testing the effectiveness of this design, this study aims to make a significant contribution to teacher education practices by presenting an example course to promote science teachers' TPACK.

There is a need for research investigating how to promote teachers' TPACK needed for using technology to support subject-specific pedagogies and evaluating the effectiveness of the methods used to prepare teachers for technology integration (Jimoyiannis, 2010). In the present study, a science content-specific TPACK course design model was created, and its effectiveness was investigated. The literature about science teachers' development of TPACK within the context of specifically designed programs is still limited; most of the studies creating instructional models to support the development of TPACK were conducted with pre-service teachers. In addition, empirical evidence is needed to design successful programs in developing teacher knowledge of technology integration (Niess, 2013). Therefore, the findings of the present study contribute to the research efforts of investigating TPACK development of teachers by using graduates of science education programs as participants'.

In addition, even though the TPACK research literature has grown rapidly, there is still limited research investigating science teachers' development of TPACK in detail; much more research is needed to be able to understand the issue clearly (Koh & Chai, 2014). Most of the studies were focused on measuring components of TPACK from an integrative perspective; the studies investigating the TPACK component as a separate construct from a transformative perspective are still limited (Archambault & Crippen, 2009; Kabakçı Yurdakul et al., 2012). Moreover, in Turkey, mostly quantitative methods were employed in the TPACK studies; there is a need for qualitative and mixed-methods studies to better understand the framework in our national context (Baran & Canbazoğlu-Bilici, 2015). For this reason, the findings of this study can make a contribution to the literature by exploring TPACK development from a transformative approach and providing detailed explanations about participants' TPACK development using qualitative data.

Lastly, the course design process, course content, and course activities are described in detail in the present study. This information can be useful for researchers and teacher educators aiming to design courses and/or programs to support teachers' TPACK development. Since multiple guiding principles were used while designing the study, and these principles were matched with specific course activities, it would be easy to change the structure of the course by adding/removing principles and adapting them according to the specific needs of a particular context. Teacher educators and researchers may adapt and implement the proposed course design according to their contexts and the needs of their audience. In addition, even though T-A-P course design was created for graduate education, the guiding principles and main stages of the design can be informative while designing interventions for pre-service teachers' TPACK development. The course content and activities might be heavy for pre-service teachers to handle; therefore, it can be adapted by decreasing the number of assignments and readings.

CHAPTER 2

LITERATURE REVIEW

In the present study, a graduate course was designed to promote graduate science education students' TPACK development, and the change in graduate science education students' level of TPACK, perceived competencies of TPACK, and self-efficacy of TPACK after attending that course was examined. In order to design that course, the related literature was reviewed. This chapter presents a brief summary of the reviewed literature. First, the TPACK framework is explained. Then, research about the TPACK development of teachers is presented. Lastly, the characteristics of effective programs for TPACK development are discussed, and the course design created for the present study is explained.

2.1. Technological Pedagogical Content Knowledge (TPACK)

Shulman (1986) introduced the term *pedagogical content knowledge (PCK)* and defined this concept as teachers' ability to combine their content knowledge with their pedagogical knowledge and present subject matter knowledge in a way that is comprehensible and understandable to others for an efficient learning process. PCK framework suggests that it is not sufficient for teachers to just know about the subject matter and pedagogical strategies separately; teachers need to combine these two kinds of knowledge effectively to form PCK, which includes knowledge about organizing the content, selection of teaching methods, common student misconceptions, learner characteristics, curriculum and so on (Shulman, 1986; 1987). Since its introduction, the PCK framework has been accepted and studied excessively.

When computers entered the schools and classrooms, meaningful integration of technology and the teacher knowledge needed for effective teaching with technology became an important concern for educational research (Brantley-Dias & Ertmer, 2013). First, Pierson (2001) suggested technology knowledge component should be added to the PCK framework and argued that the intersection of three knowledge areas, technological-pedagogical-content knowledge can define the knowledge needed for effective technology integration. After that, other researchers also used the term technological pedagogical content knowledge and/or proposed similar approaches for defining teacher knowledge needed for effective technology integration, considering the relationships between content, pedagogy, and technology.

However, the TPACK framework, sometimes referred to as TPCK by other researchers, became widely popular when Mishra and Koehler (2006) explained the framework in detail and defined the components of TPACK as content knowledge (CK), pedagogical knowledge (PK), technology knowledge (TK), technological content knowledge (TCK), technological pedagogical knowledge (TPK) and pedagogical content knowledge (PCK) (Graham, 2011). In the following sub-sections, after discussing the nature of technological pedagogical content knowledge, different frameworks of TPACK are explained.

2.1.1. The Nature of TPACK

Before explaining the different frameworks of TPACK, it is important to discuss the nature of TPACK. In the literature, there are two perspectives about the epistemological nature of TPACK: the transformative model and the integrative model. Firstly, Gess-Newsome (2002) described integrative and transformative perspectives when discussing the nature of PCK. After the introduction of TPACK frameworks, researchers adapted these perspectives to interpret the nature of TPACK.

The integrative perspective suggests that TPACK is a combination of the identified components; when there is an increase in any of the components, the level of TPACK also increases. Teachers with high levels of TPK, TCK, PCK, TK, PK, and CK will also have a high level of TPACK (Schmid et al., 2020). On the other hand, the transformative perspective identifies TPACK as a unique, synthesized form of knowledge; all of the identified components are necessary and contribute to the development of TPACK; however, they do not simply add up to form TPACK (Angeli,

& Valanides, 2009; 2013; Chai et al., 2010; Graham, 2011). According to the transformative perspective, the instruction for teachers needs to target TPACK specifically; just improving some of the components does not help teachers improve their level of TPACK.

It is important for researchers to identify their perspective when studying TPACK because it has significant influences on the research questions, data collection methods, and data analysis strategies (Graham, 2011). Integrative perspective generally leads to measuring components of TPACK separately and adding them up to capture TPACK, whereas transformative perspective focuses on TPACK as a different form of knowledge on its own (Angeli, & Valanides, 2009; 2013). For this reason, researchers need to decide on their perspective of epistemological of nature before they begin to make investigations. In the present study, the transformative view of TPACK was adopted following a framework developed by Niess (2005; 2012; 2013), which will be explained in the following sub-section.

2.1.2 TPACK Frameworks

Niess (2005) argued that the developments in technological tools and the entrance of technological tools into school require the addition of technology as a central component to the PCK framework. The researcher stated that teaching with technology requires knowing technology, content, and pedagogy as well as understanding the interactions between them. In this conceptualization, TPCK is not just a set of different domains of knowledge; it is a way of thinking using these domains of knowledge (Niess, 2008). Using the components of PCK (Grossman, 1989; 1990), the knowledge and skills for teaching with technology were identified as:

> 1. An overarching conception of what it means to teach a particular subject by integrating technology into the learning;
> 2. Knowledge of students' understandings, thinking, and learning with technology in a particular subject;
> 3. Knowledge of curriculum and curriculum materials that integrate technology with learning in the subject area;
> 4. Knowledge of instructional strategies and representations for teaching particular topics with technology (Niess, 2005, p. 511).

Overarching conception is the basis for teachers' instructional decisions and refers to teachers' knowledge and belief about the nature of the subject to be taught, the important points for students to learn, and how technology can assist students' learning. Knowledge of students' understandings component includes teachers' knowledge and beliefs about students' learning with technology in specific topics which are influencing their integration of technology. Teachers use knowledge of curriculum when using different technologies to teach specific topics and organizing the subject matter knowledge to be taught in a technology-enhanced environment. Knowledge of instructional strategies shapes teachers' integration of technologies as they use technologies to meet their instructional goals and to guide students during the process of learning with technology (Niess, 2012).

Niess (2013) used the term "integrated transformation" when describing the nature of TPACK. Since content, pedagogy, and technology come together to form TPACK, it is integrated; however, since the resulting knowledge is "a distinct form of knowledge where the inputs to the knowledge have been rearranged, merged, organized, assimilated, and integrated in such a way that none are individually discernible" it is also transformative (Niess, 2013, p. 176). It is also argued that it is not possible to identify teachers as having or not having TPACK; the development of TPACK is a cognitive developmental process, as shown in Figure 2.1.

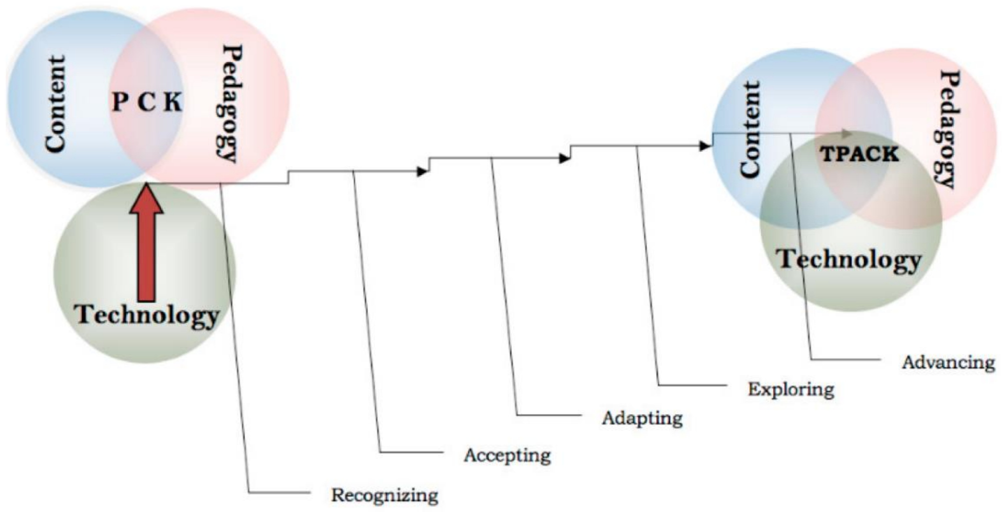

Figure 2.1 Developmental Levels of TPACK (Niess, 2012, p. 7)

Based on Roger's (1995) five step process of whether to accept or reject an innovation, Niess et al. (2006) identified progressive TPACK levels for teachers. At the *Recognizing* level, teachers can use technology and recognize its capabilities but consider it as a low level tool to learn information. At the *Accepting* level, teachers try to use technology without thinking about how to support their teaching of the subject matter. At the *Adapting* level, teachers try to integrate technology but are not confident enough to give up control; students are generally presented with low-level thinking activities managed by the prescribed worksheets. At the *Exploring* level, teachers actively use technology to try different ways of teaching and learning the content and adopt more student-centered pedagogies. At the *Advancing* level, teachers use technology in various ways, and students are presented with the opportunity to manage their own learning process with technology (Niess, 2012).

Angeli and Valanides (2005) used the term ICT (information and communication technologies) related to PCK and defined it as a teacher's ability to combine knowledge about technology, content, pedagogy, learners, and context in a way that adds the value of technology to teaching for specific contexts and learners. They identified five main competencies for ICT-related PCK as knowing how to:

> 1. Identify topics to be taught with ICT in ways that signify the added value of ICT tools, such as topics that students cannot easily comprehend, or teachers face difficulties in teaching them effectively in class.
> 2. Identify representations for transforming the content to be taught into forms that are comprehensible to learners and difficult to be supported by traditional means.
> 3. Identify teaching strategies, which are difficult or impossible to be implemented by traditional means, such as application of ideas into contexts not possible to be experienced in real life, interactive learning, dynamic and context-situated feedback, authentic learning, and adaptive learning to meet the needs of any learner.
> 4. Select ICT tools with inherent features to afford content transformations and support teaching strategies.
> 5. Infuse ICT activities in the classroom (Angeli & Valanides, 2005, p. 294).

The researchers also emphasized that these aspects should not be handled separately but considered simultaneously while designing technology-integrated lessons (Angeli & Valanides, 2005). In the later years, the researchers used the term ICT-TPCK and identified five knowledge bases as subject matter knowledge, pedagogical knowledge, ICT knowledge, knowledge of students, and knowledge of the context (Angeli & Valanides, 2009; 2013). Figure 2.2 represent the graphical representation of the ICT-TPCK framework.

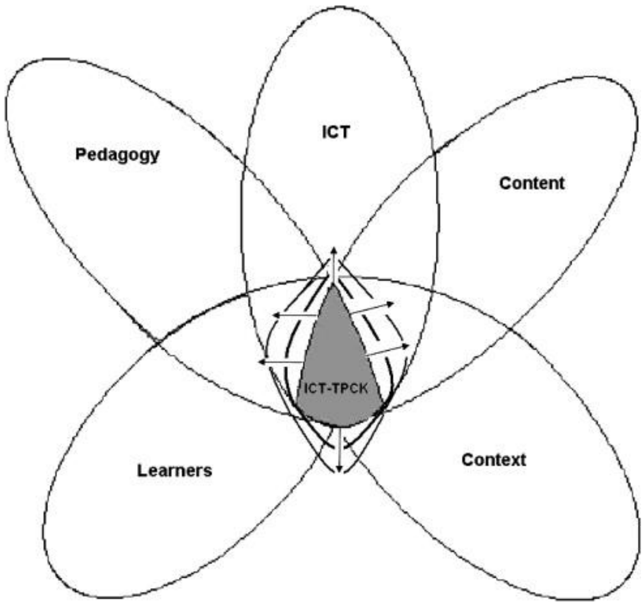

Figure 2.2 Graphical Representation of the ICT-TPCK Framework (Angeli & Valanides, 2013, p. 201)

The researchers strongly emphasized that ICT-TPCK is a transformative body of knowledge; it is not a simple combination of the knowledge bases. Knowledge bases are significant contributors, but they are not sufficient alone to capture TPCK; TPCK should be assessed according to the identified competencies (Angeli & Valanides, 2013). Even though, in the later years, the term TPACK gained significant popularity in the literature, the researchers continued to use the term TPCK to distinguish their conceptualization of technological pedagogical content knowledge.

One of the most popular frameworks of TPACK was proposed by Mishra and Koehler (2006) by extending Shulman's PCK framework with the addition of technology knowledge component in order to provide a theoretical framework related to the relationship between teaching and technology. The TPACK framework, introduced as TPCK and then changed to TPACK (Thompson & Mishra, 2007), proposes that effective teaching with technology requires a meaningful combination of content, technology, and pedagogy and emphasizes the relationships, connections, strengths, and weaknesses between and among these components (Mishra & Koehler, 2006).

In the TPACK framework, content knowledge (CK), pedagogical knowledge (PK), and technology knowledge (TK) pair up to form three other types of knowledge besides technological pedagogical content knowledge: technological content knowledge (TCK), technological pedagogical knowledge (TPK) and pedagogical content knowledge (PCK) (Mishra & Koehler, 2006). Knowledge of context is also very important in the TPACK framework; however, it was not defined as an element of the TPACK framework at the beginning. It was included in the framework to represent the influence of context on TPACK. However, since it was neglected in many TPACK studies, contextual knowledge (XK) was added to the framework as an element in later years (Mishra, 2019). Figure 2.3 presents the updated version of the TPACK diagram.

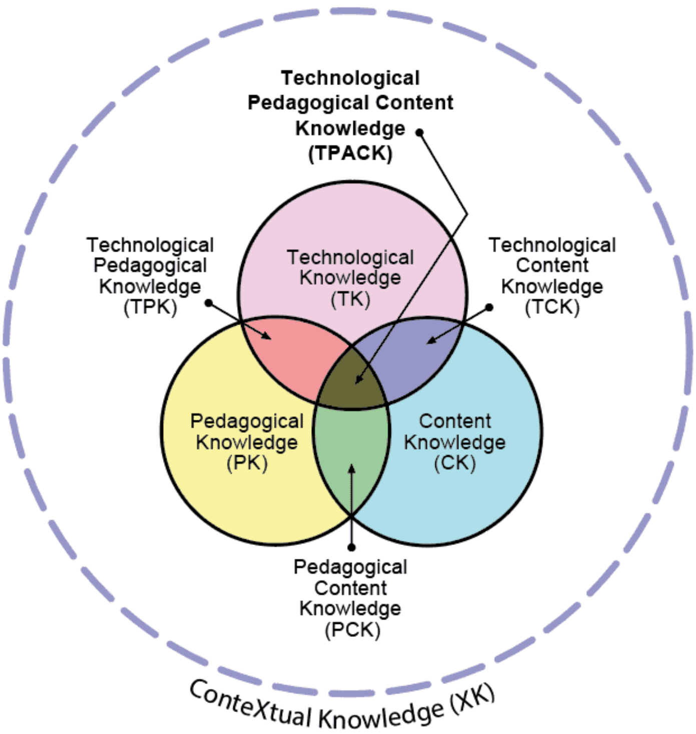

Figure 2.3 Revised Version of the TPACK image

Content knowledge is the knowledge about the subject matter to be taught and learned, including concepts, theories, facts, principles, nature of knowledge, and inquiry (Shulman, 1986; Mishra & Koehler, 2006). Teachers need to have solid knowledge about their field as well as an understanding of the procedures of obtaining that knowledge. Pedagogical knowledge includes knowledge about the processes of teaching and learning. It includes knowledge about learner characteristics, teaching methods, developing and implementing of lesson plans, classroom management, assessment, and evaluation (Shulman, 1986; Mishra & Koehler, 2006).

Since technology is always changing and evolving, it is difficult to define what constitutes technology knowledge. At first, it was described as a teacher's knowledge about standard and advanced technologies and the ability to operate those technologies (Mishra & Koehler, 2006). Then, Cox and Graham (2009) argued that technology knowledge in the TPACK framework should be limited to emerging technologies which are typically digital technologies. Knowledge about transparent technologies (e.g., books, chalkboards, pencils) should not be included in technology knowledge since they are no longer considered as technologies. Most of the researchers using the TPACK framework also described knowledge of technology as the knowledge of emerging technologies, digital technologies, and/or information technologies (e.g., Koehler et al., 2013; Lin et al., 2013; Roussinos & Jimoyiannis, 2019; Tondeur et al., 2020). In the educational literature, the terms technology, digital technologies, information and communication technologies (ICT), and information technologies are used interchangeably to refer to digital devices, and the content reached via these devices.

Pedagogical content knowledge refers to teachers' ability to integrate their subject matter knowledge with their pedagogical knowledge, including the ways of communicating subject knowledge in ways that are understandable to learners for an efficient learning process (Shulman, 1986; Mishra & Koehler, 2006). It refers to how teachers transform the content to be taught in a way that is suitable for the learners and the context.

Technological content knowledge is an understanding of the relationship between content and technology, including the ability to evaluate how they can support or constrain another (Mishra & Koehler, 2006). Teachers should know how technological tools can be used to transform the content to be taught as well as how the content shapes the use of technology (Koehler & Mishra, 2009). It requires an understanding of the affordances and limitations of technology to represent the content effectively.

Technological pedagogical knowledge refers to the knowledge about various technological tools to be used in particular teaching and learning situations and the ability to combine the pedagogical strategies with the appropriate technologies (Mishra & Koehler, 2006). It requires an understanding of how technology can change the teaching and learning processes (Koehler & Mishra, 2009). Teachers need to be able to evaluate the strengths and weaknesses of a technological tool to improve their teaching as well as students learning.

Contextual knowledge includes a teacher's knowledge about the available technologies, national policies, school environment, and every unique information about their classroom circumstances (Mishra, 2019). Contextual factors influence the relationships between content, pedagogy, and technology and how they are combined by the teacher.

In this framework, TPACK is the emergent form of knowledge that results from the interactions and combinations of content, technology, and pedagogy and includes a teacher's knowledge about different technologies for content representation, pedagogical strategies that use technologies effectively to teach the content, how technology can be used to make a concept more understandable for students, and how to use different technologies to help students construct new knowledge (Mishra & Koehler, 2006). It is also argued that there is no single best way for technology integration into education; integration efforts should be designed creatively according to the subject matter to be taught and specific classroom contexts (Koehler et al., 2013). Even though the researchers strongly emphasized that TPACK is a different type of knowledge and requires a transformation, they did not specify their perspective on the nature of TPACK. However, later research by developers of this framework and most of the studies using this framework, measured the components of the TPACK to capture teachers' level of TPACK. Therefore, this framework was considered to be following the integrative view of TPACK (Angeli & Valanides, 2009; Graham, 2011).

Lee and Tsai (2010) used the TPACK framework by Mishra and Koehler (2006) as a basis and developed Technological Pedagogical Content Knowledge-Web (TPCK-W) framework. They replaced the technological knowledge component in the original framework with the knowledge of the Web component. In this framework, knowledge of the Web refers to the knowledge of the use of Web-based technologies. The researchers argued that the Web is an important technology for education and teaching with the Web requires more complex knowledge than TPCK. In a similar way, Jimoyiannis (2010) developed the Technological Pedagogical Science Knowledge (TPASK) framework based on components of the TPACK framework to propose a science content specific framework for teachers' preparation. They replaced the content knowledge component with science knowledge and identified knowledge components and descriptions for all components of the TPASK framework.

Porras-Hernandez and Salinas-Amescua (2013) used the ICT-related PCK framework (Angeli & Valanides, 2005) as a foundation to propose a strengthened framework for TPACK. They argued that the context in this framework is vaguely defined; however, it is an important element of the framework as a knowledge component for teachers and as a factor influencing teacher practices. They proposed two dimensions to describe the context: (1) Scope; macro, meso, and micro level contexts; and (2) Actor: students' and teachers' contexts. Macro context includes social, political, technological, and economic conditions as well as technological developments and national and global policies. Meso context is defined by the social, political, cultural, organizational, and economic conditions of the local community and the institution. Micro context refers to the conditions of the classroom, including available resources, norms, beliefs, and goals of teachers and students. Students' and teachers' contexts refer to unique characteristics of teachers and students, including their needs, beliefs, ethnicity, and socio-economic status.

Yeh et al. (2014) proposed the TPACK-P framework to account for the influence of teachers' experiences in the development of TPACK. Using the Delphi technique, experts' ideas were collected, and eight knowledge dimensions and 17 indicators were identified. These eight dimensions belong to three main knowledge domains: (A) knowledge of learners, including (1) using ICT to understand students, and (2) using ICT to assess students; (B) knowledge of planning and designing, including (3) using ICT to understand subject content, (4) planning ICT-infused curriculum, (5) using ICT representations to present instructional representations, and (6) employing ICT-integrated teaching strategies; (C) knowledge of classroom instruction including (7) applying ICT to instructional management, and (8) infusing ICT into teaching contexts (Hsu et al., 2015). This framework suggests that actual teaching practices help the development of TPACK-P and increase the quality of technology integrated instruction.

TPACK is a complex concept, and there are different interpretations in the literature which resulted in different frameworks. Voogt et al. (2013) suggested that different views of TPACK in the literature can be classified as TPACK as extended PCK, TPACK as a distinct body of knowledge, and TPACK as the interactions between three domains of knowledge. All of these different approaches have been studied extensively in the literature to get a comprehensive understanding of the TPACK construct.

2.1.3. Measuring TPACK

As discussed in the previous sub-section, there are different frameworks to explain TPACK, and therefore, different types of instruments are needed to capture TPACK. For this reason, various qualitative and quantitative methods were employed in TPACK studies to examine TPACK.

Archambault (2016) conducted an extensive literature review to identify qualitative measures of TPACK. Performance assessments in the forms of lesson plan rubrics (e.g., Harris et al., 2010; Lyublinskaya & Tournaki, 2012), learning activities (e.g., Hofer & Harris, 2010), design tasks (e.g., Graham et al., 2012), case-based approaches (e.g., Kinuthia et al., 2010) are widely used to measure TPACK in the literature. In addition, interviews (e.g., Jaipal & Figg, 2010; Mishra et al., 2007) and observation tools (e.g., Hofer et al., 2011) are frequently used in TPACK studies. Most of the time researchers use more than one qualitative method of data collection for detailed investigation of the construct and for triangulation.

Quantitative measures of TPACK are generally in the form of self-reported surveys, which can be categorized as general TPACK surveys, technology specific TPACK surveys, pedagogy specific TPACK surveys, and content specific TPACK surveys (Chai et al., 2016). TPACK surveys also differ according to the nature of the TPACK framework; some of them are constructed based on the integrative view and therefore try to capture TPACK based on the identified components, and some of them use transformative view of TPACK and try to capture TPACK from a holistic perspective. Schmidt et al. (2009) developed the most used and adapted (e.g., Kaya & Dağ, 2013; Koh et al., 2010) general TPACK survey measuring pre-service teachers' self-reported perceptions of TPACK across seven components of TPACK from an integrated point of view. Kabakçı-Yurdakul et al. (2012) developed the TPACK-Deep scale based on the transformative view of TPACK. Measuring TPACK as a whole entity, this survey is composed of four factors: design, exertion, ethics, and proficiency.

Since TPACK is a complex form of knowledge, specifying it for different technologies, pedagogies and contents can help researchers assess the level of TPACK better (Chai et al., 2016). Some researchers attempted to achieve this by developing technology specific TPACK surveys trying to measure TPACK for specific technologies. For example, Lee and Tsai (2010) developed a TPACK survey for Web-based learning composed of six factors: Web-general, Web-communicative, Web-PK, Web-CK, Web-PCK, and attitude towards Web-based instruction. Similarly, Hsu et al. (2013) designed a technology specific survey for game-based TPACK composed of three factors: game knowledge, game pedagogical knowledge and game pedagogical content knowledge.

TPACK for Meaningful Learning survey is an example of pedagogy specific TPACK survey developed by Chai et al. (2011) based on the components of the TPACK framework. Examples of subject specific instruments include the TPACK-SeS scale developed by Canbazoğlu-Bilici et al. (2013) and the TPACK questionnaire developed by Jang and Tsai (2013), which were designed to capture TPACK specifically for science content.

Besides self-reported surveys, Angeli and Valanides (2005) developed a rating scale for assessing technology-integrated lesson plans for ICT-related PCK development. Using this rating scale, lesson plans were scored on ICT-related TPACK framework dimensions between 0 and 1. Kramarski and Michalsky (2010) developed a TPACK comprehension test composed of 10 open-ended questions. The answers were scored between 0 (failure to respond) and 3 (high level of comprehension).

There are also various other instruments in the literature that are not mentioned here. Especially developing quantitative instruments for measuring TPACK has been an important research interest after the introduction of the TPACK framework. Although the forms, purposes, and frameworks of the instruments vary, all of them are developed for the same purpose; capturing TPACK. When measuring TPACK, the major concerns should be selecting instruments/methods of data collection that are compatible with the framework of the study and using multiple instruments/methods to be able to capture a detailed picture of teachers' TPACK.

2.2. The Development of TPACK for Teachers

After the introduction of the TPACK frameworks, various studies have been conducted to investigate teachers' TPACK development. Since effective use of technology in teaching and learning has significant implications for improving the quality of school instruction and the quality of integration efforts depends on teachers, researchers have tried to find best practices for developing teachers' TPACK. However, there is no single perfect strategy to develop teachers' TPACK; several professional development approaches can be found in the literature. Koehler et al. (2014) grouped these efforts into three broad categories; (1) From PCK to TPACK; (2) From TPK to TPACK; and (3) Developing PCK and TPACK simultaneously.

PCK to TPACK approach is suitable when teachers already have PCK through methods courses but do not have any experience about how to integrate technology into their teaching practices. In this approach, teachers learn how to use technology to improve their current teaching practices (Koehler et al., 2014). The professional development programs following this approach try to improve TPACK by offering knowledge about technology as well as knowledge about how to effectively integrate technology into the teaching of subject matter (e.g., Harris & Hofer, 2009; Niess et al., 2010).

TPK to TPACK approach is usually the default approach used with pre-service teachers (PT) in higher education institutions. PTs learn instructional technologies in a separate course before they take a content specific teaching methods course. They learn about instructional technologies without connections to subject-specific pedagogies and content. Then, as they learn teaching methods related to their subject area, their TPK is expected to expand into TPACK (Koehler et al., 2014). In this approach, PTs take technology courses separately and are expected to apply their knowledge to their content areas.

The third approach tries to develop PTs' PCK and TPACK simultaneously, typically in the context of a subject-specific teaching methods course (Koehler et al., 2014). In this approach, instead of giving technology knowledge separately, PTs learn about the effective integration of technology while learning about subject-specific pedagogies.

While the latter two approaches are generally used with PTs, the studies with teachers generally follow the first approach based on the assumption that teachers already have PCK. In the following sub-sections, different instructional approaches designed to promote TPACK development of science teachers' are reviewed.

2.2.1. Research on TPACK Development of Science Teachers

Niess (2005) designed a one-year, graduate level program to prepare science and mathematics teachers to integrate technology into instruction. Twenty-two student teachers, who previously had earned Bachelor's degrees in their teaching areas, were enrolled in the program. In the first quarter of the program, participants attended a technology course to learn about different technologies, pedagogical considerations when using these technologies, and teaching and learning with these technologies. In the second quarter, participants attended a micro-teaching course where they learned about different teaching methods, prepared technology integrated lesson plans for each of these methods, and performed micro-teachings using their lesson plans. The second half of the program included two courses about technology and pedagogy and school experiences for the participants. During this period, participants learned how to design technology-enhanced lessons and designed and implemented their own lesson plans in real classroom settings. Data were collected through assignments, classroom observations, supervisor and cooperating teacher feedback, and student teachers' interviews. The results of the study revealed that 14 of the 22 student teachers developed TPACK, meeting the requirements of effective technology integration, whereas 8 of them were found to need more development in TPACK.

In another study, Jimoyiannis (2010) developed and implemented a program based on the TPASK framework. The coursework of the program included two modules: general theory and ICT in science education. The general module included lessons about pedagogy, teacher training methods, ICT in education, learning theories, and ICT tools. The science module included lessons about science education principles, educational technologies for science education, subject matter learning scenarios and activities, instructional design principles, and micro-teachings. Data were collected through interviews with participants. The results showed that participants developed a meaningful understanding of the TPASK framework, improved their ability for ICT integration into science education, and increased their willingness to use ICT in their classrooms. In addition, the difficulties faced by teachers during ICT integration were also investigated and found as the need to cover curriculum, textbook restrictions posed in instructional practices, the need to prepare students for the exams, the lack of time, and the school's resistance to changes. It was concluded that for the development of TPASK, teachers need authentic learning experiences and continuous feedback.

To develop science teachers' TPACK specific to the integration of interactive whiteboards (IWB), Jang (2010) developed the TPACK-COIR model (TPACK Comprehension, Observation, Instruction, and Reflection) based on the peer coaching model by (Joyce & Showers, 1995). The researcher limited the technology component to interactive whiteboards and the content component to the heat and temperature topic. In this model, during the *Comprehension* stage, science teachers studied the content in teams. In the *Observation* stage, one of the teachers demonstrated his teaching of the topic with IWB; his peers and the researcher observed his teaching and gave comments and suggestions. During the *Instruction* stage, teachers prepared activities to teach the topic with IWB, implemented them in their actual classrooms, and video recorded their implementations. In the *Reflection* stage, participant teachers watched each other's implementation, shared their experiences, and evaluated their own performances. Data were collected through written assignments, reflective journals, and interviews. The findings of the study revealed that IWBs helped teachers when teaching the heat and temperature topic by providing the use of different representations of the concepts. In addition, giving and receiving feedback from each other helped science teachers improve their skills in teaching with technology.

Niess et al. (2010) tried to improve science and mathematics teachers' TPACK within the context of a graduate course about the use of spreadsheets. The researchers designed the course content in four units. First, participant teachers explored the use of spreadsheets for teaching specific topics of science and mathematics and engaged in whole group discussions. Second, the teachers learned and discussed the skills for spreadsheets within different themes and units. Third, the teachers were asked to consider strategies for the assessment of students' outcomes while solving problems with spreadsheets. Fourth and last, participant teachers designed electronic portfolios including spreadsheet problems, plans for incorporating these problems into their instruction, and a reflection on integrating spreadsheets into their instruction. Data were collected by means of observations, interviews, online discussion transcripts, and all course assignments. At the end of the course, participant teachers expressed positive views about the course design. The findings revealed that some of the teachers achieved higher levels of TPACK, whereas the TPACK level of some teachers did not improve significantly. However, the course was found to be helpful in terms of increasing their self-efficacy of TPACK.

Figg and Jaipal-Jamani (2013) proposed a TPACK-based Professional Learning Design Model (PLDM) composed of four stages: (a) modeling a technology enhanced learning activity, (b) integrating ‘pedagogical dialogue’ in a modeled lesson, (c) tool demonstrations, and (d) applying TPACK knowledge to the design of activity. Findings from the implementation of a four-week professional development program based on this model designed to improve science teachers’ TPACK about using blogs revealed that participants found modeling a technology enhanced learning activity helpful for them to design their own activities (Jaipal-Jamani & Figg, 2015). The teachers’ level of TPACK was improved at the end of the program.

Baran et al. (2016) designed and implemented a TPACK-based professional development program and investigated its effect on science teachers’ perceptions of their TPACK development. The TPACK-based PD program aimed to develop science teachers’ awareness about domain-specific technologies, improve their knowledge about technology integration into science classrooms, and increase their self-efficacy of TPACK. The program is composed of three sections: introductions, modules, and final remarks. The introduction section included warm-up activities, TPACK presentations, introduction of the TPACK lesson design project, and the formation of teacher groups. The modules section included the presentation of various technological tools by the researchers, design activities for teachers using the tools presented, and teacher presentations of their work, discussions, and feedback. The final remarks section included project presentations, feedback, discussions, and evaluation forms. Data were collected by means of KWL charts and evaluation forms. At the end of the program, participant teachers stated that the program positively influenced their TK, TCK, and TPACK. Teachers also emphasized that designing technology-integration materials and collaborating with their colleagues and researchers improved their PK. Learning about various technologies helped teachers develop their TK, and interacting with domain-specific technologies improved their TCK. Lastly, participant teachers stated that designing a science lesson with the integration of technology helped them improve their level of TPACK.

Koh et al. (2017) proposed a professional development framework for the development of TPACK-21CL, TPACK for 21st century learning. They identified TPACK-21CL as a pedagogy-specific form of TPACK; their aim was to develop teachers' TPACK when using teaching strategies to improve students' 21st century skills. Their professional development process included five sequential steps. First, teachers designed a lesson plan and assessed it using the rubric developed by the researchers. Then, in the second step, teachers were asked to identify what needs to be improved in their plans and set goals for improving them after redesigning their plans. For the third step, design teams were formed, and as a team, they attended weekly co-design sessions with the researchers for 6 months to achieve their goals. During the fourth step, the teachers implemented and recorded their lesson plans and evaluated the student outcomes. In the last step, the teachers were asked to reflect on their implementation and student outcomes and to identify ways of improving their lesson plans. Data were collected by means of surveys, lesson plans, and teacher reflections. The findings of the study revealed that teachers' perceived confidence in designing 21st century lessons enhanced by ICT integration was increased at the end of the program. In addition, redesigned lessons increased students' performance, and the participants found the program helpful in terms of improving their ability to design ICT supported 21st century lessons.

Review of the different instructional approaches for TPACK development of science teachers revealed that design activities, external support, and feedback were generally used and found to be helpful by teachers for TPACK development. In addition, teaching experiences were included in most of the approaches, which provided teachers a chance to reflect on their development. However, the literature about science teachers' development of TPACK within the context of specifically designed programs is still limited; most of the studies creating instructional models to support the development of TPACK were conducted with pre-service teachers. For this reason, some of the instructional design models developed for pre-service teachers were also reviewed in the following sub-section.

2.2.2. Models for TPACK Development of Teachers

Improving the TPACK of pre-service and in-service teachers has been major research interest in recent years (Baran et al., 2016; Mouza, 2016). For in-service teachers, generally, short professional development programs were created and implemented and for pre-service teachers, generally, the courses within the teacher education programs were revised. Designing a course for TPACK development of teachers requires the identification of important elements of effective programs.

Learning by design approach developed by Koehler et al. (2004) to promote the development of faculty members' and graduate students' TPACK by making them work in groups to solve ill-structured real-world problems of teaching with technology. In a master's level course of educational technology, groups composed of one faculty member and three or four graduate students were formed, and they were assigned to design an online course to be taught during the next semester. Course content included readings, discussions, preparing a prototype for the course design, technology explorations, peer review, and feedback. Each class period included two main parts; discussion of the readings and issues as a whole group, and working on the projects in small groups. The design task required groups to develop the course syllabus, determine the readings, assignments, and assessment rubrics, and decide how technology would be used. Researchers stated that design-based activities provide a rich context for learning and help learners gain a deep understanding of the relationships between technology, pedagogy, and content, as well as giving them a chance to apply their knowledge to real-world problems (Koehler et al., 2004; Koehler & Mishra, 2005). Other researchers also used the learning by design approach to develop teachers' TPACK (e.g., Baran & Uygun, 2016; Boschman et al., 2015; Koh et al., 2014). In general, this approach requires forming teacher groups to design a technology-enhanced solution to a given teaching problem through iterative cycles of designing, analyzing, and re-designing (Voogt et al., 2015; Yeh et al., 2021). Engaging in design activities as a group help teachers share their expertise, learn from each other, and discuss different perspectives.

Tondeur et al. (2012) reviewed 19 qualitative studies and developed a SQD-model (synthesis of qualitative evidence) to identify best practices to prepare pre-service teachers to integrate technology into their future classrooms. The findings of this review revealed 12 key themes that should be present in education programs. Figure 2.4 presents the proposed SQD model.

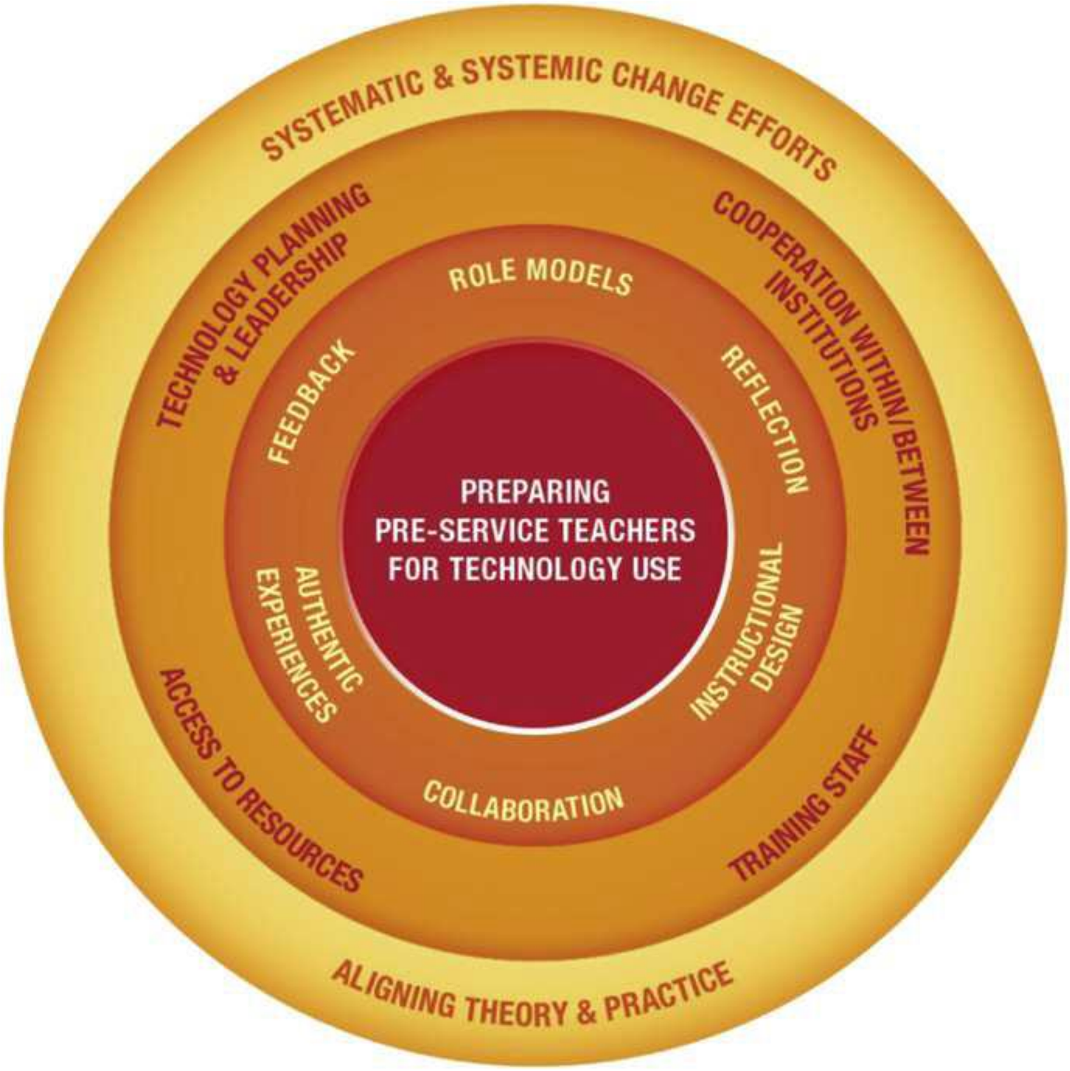

Figure 2.4 SQD Model to Prepare Pre-Service Teachers for Technology Use (Tondeur et al., 2012, p. 8)

In this model, the key themes were categorized as themes directly related to the preparation of pre-service teachers and themes about the necessary conditions to implement such programs at the institutional level. Themes related to the preparation of PTs are: (1) aligning theory and practice, (2) using teacher educators as role models, (3) reflecting on attitudes about the role of technology in education, (4) learning technology by design, and (5) collaborating with peers, (6) scaffolding authentic technology experiences, (7) moving from traditional assessment to continuous feedback. Institutional level themes are related to the conditions necessary to implement such programs, including (1) technology planning and leadership, (2) co-operation within and between institutions, (3) staff development, (4) access to resources, and (5) systematic and systemic change efforts (Tondeur et al., 2012).

The SQD model proposed by Tondeur et al. (2012) is very informative in identifying the characteristics of an intervention aiming to develop teachers' TPACK. Specifically, the themes directly related to the preparation of PTs can help researchers develop effective programs to promote TPACK development.

Teacher's role as a designer of technology-enhanced learning environments is also found to be very important for improving TPACK. Engagement in design activities provides teachers opportunities for learning TPACK, fosters creativity when repurposing technology to improve students learning, and increase their confidence to use technology through active involvement (Voogt et al., 2016). For this reason, the learning by design approach developed by Koehler et al. (2005) has been widely used to develop teachers' TPACK and found to be effective in numerous studies. (Yeh et al., 2021). Design based experiences help teachers put their theoretical knowledge into action and explore the interactions between content technology and pedagogy.

Since different kinds of design contexts and experiences were found to be effective in improving teachers' TPACK, Baran and Uygun (2016) reviewed the relevant literature to identify the main principles of design-based learning (DBL). Figure 2.5 presents the principles of design-based learning to improve TPACK.

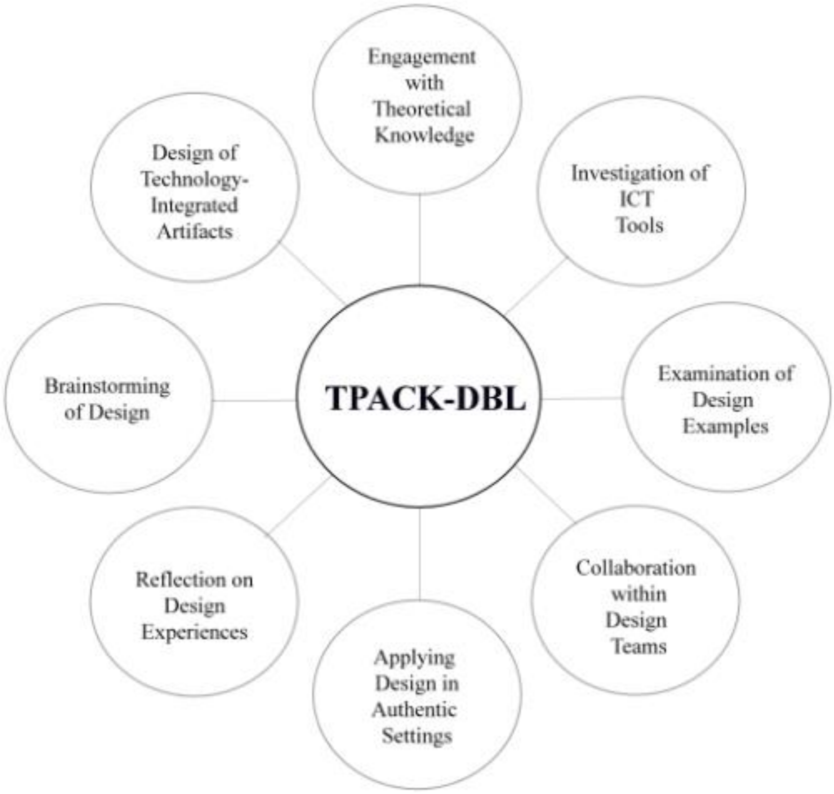

Figure 2.5 TPACK-DBL Principles (Baran & Uygun, 2016, p. 49)

According to these principles, discussing different design ideas, designing technology-integrated instructional materials, examining existing design solutions, and exploring different technologies are important characteristics of design-based learning environments (Baran & Uygun, 2016). In addition, engaging with theoretical knowledge to build a foundation for teaching with technology was also identified as an important principle.

Angeli and Valanides (2009) argued that the technology mapping approach could be used to improve teachers' TPACK. They proposed an instructional design model (Figure 2.6) based on technology mapping approach to guide teacher thinking about the complex problem of designing technology-enhanced learning.

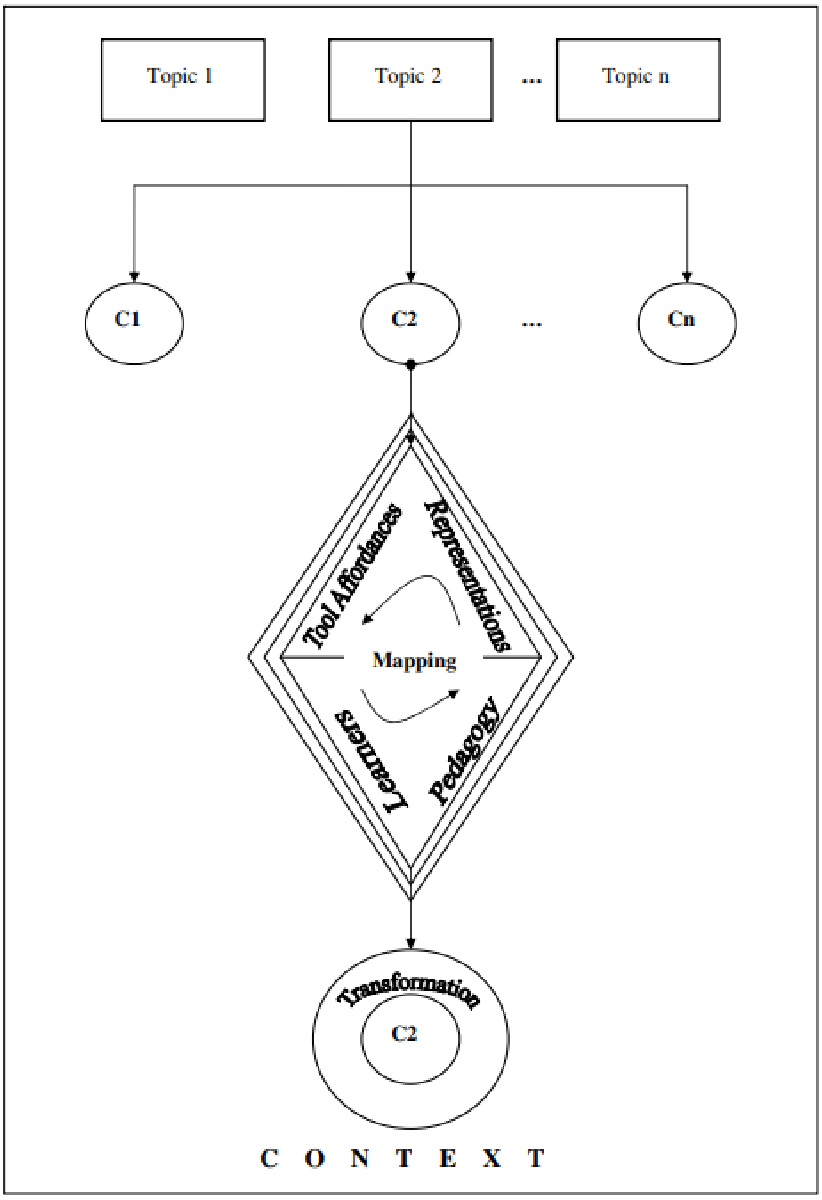

Figure 2.6 Instructional Design Model for the Design of Technology–Enhanced Learning (Angeli & Valanides, 2009, p. 160)

According to this instructional design model, teachers should be guided to think about the content of their design by considering the alternative conceptions of students and difficulties associated with the teaching of that topic. Then, teachers should be guided to think about how technology can help to create powerful representations of that topic according to the needs of learners and to transform their pedagogical practices. Technology mapping is a critical element of this design and refers to "the process of establishing connections or linkages among the affordances of a tool, content, and pedagogy in relation to learners' content-related difficulties" (Angeli & Valanides, 2013, p. 204). According to the researchers, just teaching about how to use a technological tool is not enough for teachers to understand the educational affordances of that technology. For this reason, educational affordances of technological tools should be made explicit for teachers with the help of discussions and design activities.

Lee and Kim (2014) reviewed the literature and proposed four guidelines to create an instructional design (ID) which are:

1. Explicit, systematic procedures should be included in the instructional design (ID) model to provide practical solutions for teacher training programs to enhance pre-service teachers' TPACK.
2. Stages to introduce the TPACK framework and to demonstrate TPACK examples should be included in the ID model to build pre-service teachers' knowledge base of technology integration and to prepare them to design technological artifacts for teaching.
3. Design-based learning activities such as creating a lesson plan and associated digital artifacts should be included in the ID model to prompt pre-service teachers to analyze the content and student learning needs.
4. A cyclic design-based learning process should be included in the ID model to offer the opportunities for pre-service teachers to go through the design process more than once (Lee & Kim, 2014, p. 443).

Based on these principles, the researchers created the TPACK-IDDIRR (Introduce, Demonstrate, Develop, Implement, Reflect, and Revise) model (Figure 2.7) to be implemented in a multidisciplinary technology integration course for the TPACK development of pre-service teachers.

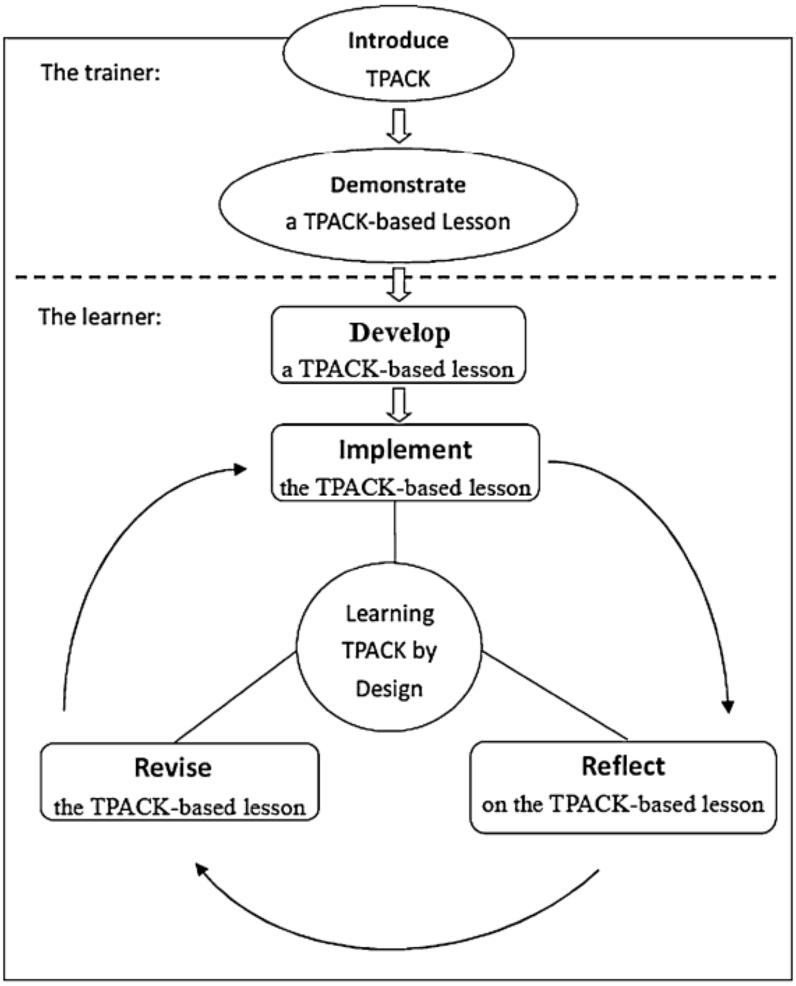

Figure 2.7 TPACK-IDDIRR Model (Lee & Kim, 2014, p. 444)

In this model, *Introduce* stage aims to develop a knowledge base of TPACK to promote pre-service teachers' learning in design activities. *Demonstrate* stage includes the demonstration of the technology-enhanced lesson by the instructor of the course. *Develop, Implement, Reflect,* and *Revise* stages includes iterative learning activities for pre-service teachers. During these stages, working in groups, pre-service teachers develop a technology-enhanced lesson plan; one of the group members implements this plan as micro-teaching, then they reflect on their performance and revise their plan accordingly. The revised version of the plan is implemented by another group member, and the iterative cycle of implement-reflect-revise continues until each group member performs micro-teaching (Lee & Kim, 2014). This model emphasizes the importance of building a theoretical foundation, designing and implementing technology-based lesson plans, and a chance to revise the initially designed plans.

The models and their guiding principles explained in this section were used when designing the "Theory-Application-Practice (T-A-P) Course Design" aiming to improve graduate science education students' TPACK. The next section explains how the stages of this course design were determined based on the existing literature.

2.2.3 Principles of the Theory-Application-Practice (T-A-P) Course Design

The review of the literature emphasized the importance of building a theoretical foundation, examining technology-integrated lesson materials, investigating different technological tools, engaging in design activities, implementing technology-enhanced lesson plans, and giving and receiving feedback for teachers' development of TPACK. Accordingly, in the present study, a course design was developed to be implemented in *Teaching Science with Technology* course based on these principles. The guiding principles of this course design and how they are reflected in the course activities are explained one by one.

1. Building a theoretical foundation is important for teachers' TPACK development.

Learning about theories of technology integration can help teachers develop meaningful learning materials enhanced with technological tools (Baran & Uygun, 2016; Lee & Kim, 2014; Tondeur et al., 2012). In order to promote the TPACK development of teachers, providing them with theoretical information about technology integration is important. For this reason, in T-A-P course design, teachers were assigned to read articles, write reflections and prepare discussion questions about them. During the first five weeks of the course, the instructor prepared a presentation about the selected articles, including teachers' discussion questions, and the selected articles were discussed in the classroom. In addition, participants were engaged in different in-class activities about the theoretical foundations of the TPACK framework (e.g., defining components of the framework, identifying teacher competencies for technology integration, and TPACK game).

2. Examining examples of technology-integrated learning materials promotes teachers' development of TPACK.

Examination of existing technology-integrated learning materials gives teachers a chance to explore different design ideas and make them think deeply about the interactions between content, pedagogy, and technology (Baran & Uygun, 2016; Mouza et al., 2014). In addition, the examination of different materials may help teachers gain different perspectives and find inspiration for their design processes. For this reason, in T-A-P course design, teachers were provided with example lesson plans in week 5 and guided to discuss the quality of technology integration in that plans. In addition, participants shared all of their lesson plans with each other on the course page in the learning management system (LMS) of the university. They were also assigned to examine at least two of their friends' lesson plans and provide feedback.

3. Investigation of technologies using the technology mapping approach promotes the TPACK development of teachers.

Examination of different technologies is a common element of programs aiming to develop teachers' TPACK. However, just presenting different technological tools is not enough for teachers to identify how these tools can be used to support the teaching of the content (Angeli & Valanides, 2009; 2013). For this reason, when learning about different technologies, teachers should be guided to identify and discuss educational affordances, limitations, and uses of particular technological tools. For this reason, in T-A-P course design, teachers investigated the technologies selected by the instructor working in groups, determined affordances, limitations, and potential uses of each particular tool in science teaching, and discussed their ideas as a whole class. In addition, teachers formed groups, and each group selected a technological tool, presented it to the class, and showed an example application.

4. Designing technology-enhanced learning materials improves teachers' TPACK.

Almost all of the studies about the development of teachers' TPACK suggest that designing learning materials with the help of technology is an effective way of improving TPACK. Engagement in design activities helps teachers apply their theoretical knowledge to specific situations, fosters creativity, and promotes TPACK (Baran & Uygun, 2016; Koehler et al., 2005; Lee & Kim, 2014; Voogt et al., 2016). For this reason, in T-A-P course design, teachers prepared four technology-integrated lesson plans. In addition, they were provided with a lesson plan format (Appendix B), including questions about the interactions between content, technology, and pedagogy of their lesson plans to help them think deeply while preparing lesson plans.

5. Implementing technology-integrated lesson plans and reflecting on the experiences contribute to the development of TPACK.

As well as designing learning materials, implementing them is also very important for the TPACK development of teachers since it gives teachers a chance to reflect on their performance. Implementing lesson plans and reflecting on those experiences can help teachers identify the difficulties they face while teaching with technology, assess their performance, and promote their TPACK (Baran & Uygun, 2016; Lee & Kim, 2014). For this reason, in T-A-P course design, each participant performed a micro-teaching and wrote a reflection paper about their micro-teaching experience.

6. Providing feedback about teacher designs is important for TPACK development.

Teachers need support and feedback when learning to design technology-integrated lesson materials. Feedback from the instructor as well as from other participant teachers is important for teachers' development of TPACK. Feedback help teachers identify the shortcomings of their design and give them a chance to refine their designs (Tondeur et al., 2012; Lee & Kim, 2014). For this reason, in T-A-P course design, teachers were assigned to provide feedback to the lesson plans of other participants. In addition, the instructor provided detailed feedback to all lesson plans of teachers to help them improve their technology integration practices.

Based on these principles, the course content and activities are determined, categorized under three stages, and put in a meaningful order. The first stage of the course design is *Theory* designed to gain graduate science education students an understanding of the theoretical principles of the TPACK because having theoretical knowledge is the foundation of TPACK development. The second stage of the course design is *Application,* during which teachers examine various technological tools as well as discuss their integration into science teaching. The third and last stage of the course design is *Practice* designed to make teachers put their newly gained theoretical knowledge and technology knowledge into action by performing micro-teachings. Detailed explanations about the course content and activities are presented in the methodology section.

CHAPTER 3

METHODOLOGY

The purpose of this study was to design a graduate course to promote graduate science education students' TPACK development and investigate how graduate science education students' level of TPACK, perceived competencies of TPACK, and self-efficacy of TPACK changed after attending that course. In this chapter, after explaining the research design, information about the content, syllabus, and activities of the designed course are presented. In addition, participants, data collection, and analysis procedures are explained. Lastly, the issue of trustworthiness, limitations, assumptions, and ethic are discussed.

3.1. Design-Based Research

The main purpose of this research was to design and implement a graduate course that will help graduate science education students' (1) develop an informed understanding of the TPACK framework and its implications for science education; (2) gain required knowledge and skills to combine technology and pedagogy effectively for teaching science content; (3) experience the technology integration process while preparing lesson plans for teaching science. In order to achieve these aims, design-based research methodology was employed in the present study.

Design-based research (DBR) can be described as "a series of approaches, with the intent of producing new theories, artifacts, and practices that account for and potentially impact learning and teaching in naturalistic settings" (Barab & Squire, 2004, p.2). Design-based research emerged to carry out formative research in order to evaluate and modify educational designs based on findings of previous research (Collins et al., 2004). DBR, developed and used by educators, aims to increase the impact of educational research on real-life practices (Anderson & Shattuck, 2012).

Van der Akker et al. (2006) summarized the main purposes of DBR as:

1. To strengthen the link between educational practice and research;
2. To develop grounded theories by studying the process of learning and the ways of improving that process;
3. To improve the robustness of design practice.

Design-based research, which is sometimes called as design research, design experiments, or development research in the literature, is a way of developing and implementing practices within scientific research principles to improve real-world practice. DBR focuses on investigating the effectiveness of a particular intervention which can be a type of assessment, or an instructional approach, or a technology-based intervention, and so on (Anderson & Shattuck, 2012).

DBR approach is similar to how engineers create a product. Researchers identify a problem and design a solution for that problem using theory and previous research. Then, this potential solution is tested in a real-world setting, and its effectiveness is evaluated. Lastly, the researcher analyzes the results of this test and determines which parts of the solution are working and which are not, and starts a new cycle of testing after making necessary revisions (Scott et al., 2020).

DBR has begun to be used more frequently as a research methodology in recent years, and there are different definitions provided by different researchers. Some of these definitions mainly focus on the development of a theory, some others focus on improving practice and/or creating a product, and some fail to address either of them (Christensen & West, 2018). Even though definitions of DBR vary in the literature, there are some common characteristics of the methodology mentioned by various researchers. These common characteristics are identified by Christensen and West (2018) and summarized in Table 3.1.

Table 3.1

Characteristics of Design-Based Research

Characteristic	Description
Design driven	Design-based research requires a design process which may range from an intervention to an instructional artifact (Anderson & Shattuck, 2012; Brown, 1992; Cobb et al., 2003; Collins, 1992; Design-Based Research Collective, 2003).
Situated	The process of design is situated in a real-world context (Anderson & Shattuck, 2012; Barab & Squire, 2004; Cobb et al., 2003).
Iterative	DBR includes multiple cycles of design, test, and revision (Anderson & Shattuck, 2012; Barab & Squire, 2004; Brown, 1992; Design-Based Research Collective, 2003; Shavelson et al., 2003).
Collaborative	Collaboration between researchers, practitioners, and others involved is required in DBR (Anderson & Shattuck, 2012; Barab & Squire, 2004; McCandliss et al., 2003).
Theory building	DBR requires making evidence-based theoretical contributions as well as creating an effective design (Anderson & Shattuck, 2012; Barab & Squire, 2004; Brown, 1992; Cobb et al., 2003; Design-Based Research Collective, 2003; Joseph, 2004; Shavelson et al., 2003).
Practical	The results of DBR should make a contribution to real-world practices (Anderson & Shattuck, 2012; Barab & Squire, 2004; Design-Based Research Collective, 2003; McCandliss et al., 2003).
Productive	In addition to making theoretical and practical contributions, the effectiveness of the design should be measured and evaluated (Barab & Squire, 2004; Design-Based Research Collective, 2003; Joseph, 2004; McCandliss et al., 2003).

In contrast to the belief that a research process can be tainted by the influence of the researcher, in design-based research, the researcher manages the research process in cooperation with the participants and constantly design, implement and revise the intervention (Wang, & Hannafin, 2005). Researchers should fulfill the roles of researcher, project manager, theorist, and designer when conducting DBR (Christensen & West, 2018). In addition, DBR requires the use of a variety of different approaches for data collection and analysis, such as surveys, interviews, observations, and comparative analysis (Wang & Hannafin, 2005).

Gravemeijer and Cobb (2006) argued that there are three distinct phases of design-based research. The first phase is preparing for the experiment, where the researchers clarify theoretical intent and propose a course design by considering the learning goals, instructional activities, and students' thinking and understanding. In the present study, the first phase included preparing an instructional course design named "Theory – Application – Practice (T-A-P)" based on the findings of the previous research studies aimed at developing science teachers' level of TPACK (e.g., Angeli, & Valanides, 2013; Jang & Chen, 2010, Koh & Divaharan, 2011).

The second phase of DBR is experimenting in the classroom, where researchers conduct the design experiment in the classroom, continuously collect data, and evaluate the design at the same time. In the present study, the T-A-P course design had been implemented for two semesters. During these semesters, graduate science education students were asked to write weekly feedback about each class meeting. The researchers analyzed this feedback weekly to improve the design continuously. In addition, in order to investigate the change in participants' level of TPACK, self-efficacy of TPACK, and perceived competencies of TPACK, data were collected during this stage by means of various quantitative and qualitative instruments such as questionnaires, interviews, and lesson plans.

The last phase of DBR is the retrospective analysis, where the entire data set is collected, implementation is finalized, and the researchers analyze data for the improvement of the instructional design.

Moreover, typical design-based research includes two or more iterative cycles; after the first implementation and data analysis, the researchers make necessary changes to the proposed design to improve its effectiveness (Herrington et al., 2007). For this reason, the present study included two iterative cycles. Figure 3.1 presents how each phase took place in the present study in each cycle.

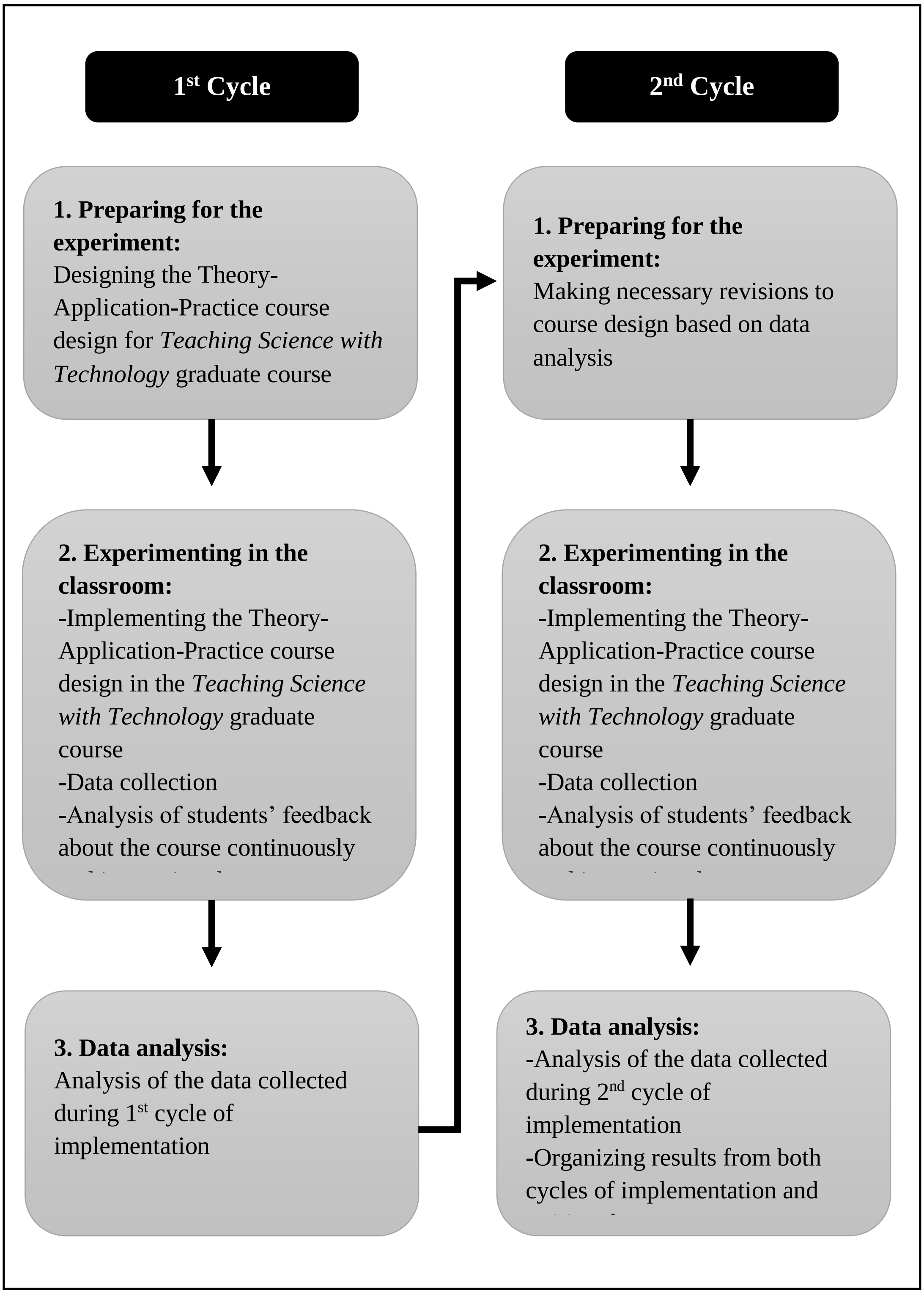

Figure 3.1 Implementation of DBR Phases in the Present Study

In the present study, the general principles and characteristics of DBR were followed to present a strong link between theory and practice by designing a graduate course based on theoretical principles and assessing its effectiveness in practice. The details of the course are presented in the following section.

3.2. Teaching Science with Technology Graduate Course

The first phase of DBR, *preparing for the experiment*, includes determining the purpose of the research and proposing an effective design to reach this purpose. For this reason, relevant literature was reviewed in detail, and common characteristics of effective programs for developing science teachers' level of TPACK were determined. Since the target audience of this design was graduate science education students with a bachelor's degree in elementary science education, the course design was created based on the assumption that participants would have pedagogical knowledge and content knowledge related to elementary science education. Therefore, the course design mainly focused on increasing technological knowledge and helping participants gain the required knowledge and skills to combine technology and pedagogy effectively for teaching science content. The course objectives were stated as:

1. To analyze the TPACK framework and its implications for science education;
2. To discuss the importance, advantages, and disadvantages of technology integration into science education;
3. To develop an awareness related to the characteristics of educational technologies that can be used to improve the quality of science teaching and learning;
4. To examine various technologies that can be used in science education;
5. To engage in technology integrated lessons throughout the course;
6. To examine and reflect upon technology integrated science lesson examples;
7. To experience the technology integration process while preparing lesson plans and activities for teaching science;
8. To design a unit of instruction for a science topic using the TPACK framework;

9. To develop technological skills to be able to combine technology and pedagogy effectively for teaching science content;
10. To develop an interest in research on technology integration into science education.

The course was offered to the students of the *Elementary Science and Mathematics Education* M.S. program and *Elementary Education* Ph.D. program who were specialized in elementary science education. In the first meeting of the course, students were presented with the course syllabus, which included information about the course description, course objectives, reading list, course schedule, assignments, and grading (Appendix A). They were also informed about the present study briefly.

3.2.1. Theory-Application-Practice (T-A-P) Course Design

The course design created to be implemented in *Teaching Science with Technology* graduate course was composed of three stages named as Theory, Application, and Practice.

In the *Theory* stage of the proposed course design (lasted for five weeks), it was aimed to gain graduate science education students an understanding of the theoretical principles of the TPACK framework since it is important for learners to have solid theoretical knowledge to be able to design pedagogically meaningful learning materials (Baran & Uygun, 2016). During this stage, graduate science education students read selected articles, submitted reflections about them to the discussion forums in the LMS before each class meeting, and participated in class discussions. Moreover, since it is important for teachers to think critically about how content, pedagogy, and technology can be combined in effective instruction (Mouza et al., 2014), the participants were provided with technology integrated science lesson plan examples during this stage. It was also aimed to help the participants understand what TPACK suggests for teachers and teacher educators. If they know about the importance of technology integration and its premises for science education, they might be more motivated to integrate technology and improve themselves in this area.

During this stage, each week, participants read selected articles, submitted reflections and discussion questions about them to the discussion forums in LMS before each class meeting, and participated in the class discussions. Each week, the researcher prepared a presentation about that week's topic. The discussion questions prepared by the participants were integrated into these presentations when they were relevant. While summarizing the assigned readings of that week, the researcher also created a discussion environment with the help of discussion questions. Moreover, since it is important for teachers to think about how content, pedagogy, and technology can be combined in effective instruction critically, the participants were provided with technology integrated science lesson plan examples in week 5. Participants examined the provided examples and discussed the quality of technology integration in that plans. In addition, participants played the TPACK game in this stage to practice combining technology, pedagogy, and content effectively to teach science content. The weekly distribution of topics of this stage was as follows:

1. Technology integration into science education
2. Technological Pedagogical Content Knowledge (TPACK) framework
3. TPACK literature review: What does the research say?
4. TPACK in science education/science teacher education
5. Examination of technology integrated science lesson examples

In the *Application* stage (lasted for four weeks), it was aimed to familiarize graduate science education students with various technological tools and encourage them to discuss which content and pedagogy can be combined with those technological tools. Knowing how to use a technological tool does not mean knowing how to teach with that tool. Therefore, teacher educators should help teachers evaluate the educational affordances and limitations of a particular technological tool. As the transformative approach of TPACK suggests, knowing technology alone does not necessarily mean that teachers have the necessary abilities to integrate them into their teaching (Angeli & Valanides, 2013). That's why, while introducing the technologies, their use in science teaching was also demonstrated with the active participation of the participants.

During this stage, domain-specific and domain-free technological tools were presented to the participants, and they examined each tool one-by-one. Each week participants were provided a list of technological tools related to that week's topic, and they were asked to assess the affordances, limitations, and educational uses of each particular tool. Then, a discussion environment was created in the classroom. In addition, at the beginning of this stage, student groups were formed, and each week a group presented a technological tool that can be used in science teaching. The weekly distribution of topics of this stage was as follows:

1. Online laboratories, simulations, games
2. Mobile applications, google services
3. Social media tools, presentation programs
4. Wiki platforms, discussion groups, collaborative platforms

In the *Practice* stage (lasted for three or four weeks depending on the number of students), it was aimed to give graduate science education students a chance to put their newly gained knowledge into action. Niess (2008) argued that knowledge about teaching with technology is not enough, teachers must be provided with opportunities to apply this knowledge. During this stage, graduate science education students designed and implemented lesson plans that integrated science, pedagogy, and technology in a meaningful way, and each participant performed a micro-teaching using these lesson plans. Moreover, they also had a chance to observe each other's micro-teaching and give feedback to each other.

3.2.2. Course Assignments

Throughout the semester, there were many assignments designed to improve participants' levels of TPACK. All of the assignments were posted to the online forums in the LMS. Online forums were used because, in this way, all participants could see each other's work. In addition, most of these activities were used as the data source for the present study.

First of all, each week, participants were assigned readings related to that week's topic. Before each class meeting, participants were expected to reflect upon that weeks' readings by (1) sharing the main points they have drawn from the texts; (2) preparing at least two questions for classroom discussions; and (3) discussing how this new information can be related to real science classroom settings. Participants posted their reflections to the online discussion forum in the LMS two days before the class. They were also encouraged to read each other's reflections and share their ideas. In addition, they were assigned to find at least one article/news/activity (or something else that they think is important to share) related to the topic of that week and share it in the LMS.

Secondly, after each lesson, participants wrote feedback on that day's lesson and each other's work by sharing their ideas about (1) what can be done to improve the quality of instruction/discussion/presentation/lesson plan etc. and (2) what was the most effective part of the instruction/discussion/presentation/ lesson plan etc. Participants posted their feedback to the online discussion forum in the LMS until the next class.

Third, participants prepared four lesson plans according to the format provided to them (Appendix B). In these lesson plans, they were asked to plan to teach a science topic by choosing the right pedagogy and technology. They also shared their lesson plans with each other in the LMS until the class hours of the assigned week. They were also expected to provide feedback to at least two of their friends' lesson plans. The researcher also provided feedback to the lesson plans of participants. In addition, a face-to-face interview was conducted with each participant after they submitted their lesson plans to give them the opportunity to elaborate their ideas on their lesson plans.

Fourth, participants were assigned to make a group presentation about a technological tool that can be used in science teaching. They made a demonstration in the class and prepared a presentation report including their ideas about (1) why they chose that specific tool, (2) how that tool can improve science instruction, (3) which teaching methods and science topics can be combined with that tool.

Lastly, at the end of the semester, each participant performed a micro-teaching by presenting their third lesson plan in the classroom. They were also assigned to write a reflection about their teaching performance.

3.2.3. In-Class Activities

Throughout the semester, there were many in-class activities planned to increase graduate science education students' participation and improve their level of TPACK.

In week 1, participants were given a document including different definitions of education made by important historical figures. Participants were asked to work in pairs, review the definitions and come up with their own definitions. They were told they could use those definitions for inspiration, select one or more of them to explain their view of education, and combine two or more of them to create a new one. After each pair worked on their definitions, a classroom discussion was held about their definitions of education.

In week 2, participants were asked to form groups of two or three and write two research suggestions related to the TPACK development of science teachers. They were instructed to use transformative approach for one of the research questions and integrative approach for the other. They were also asked to specify what kind of instruments could be used for each of their research suggestions and why. After each group finalized their suggestions, each group shared their own work and gave feedback to each other.

In week 3, the Delphi technique was explained to the participants. In this technique, a group of individuals investigated a complex, open-ended question in cooperation (Linstone & Turoff, 1975). With the purpose of reaching a consensus about the given issue, the technique usually includes three or four rounds (Hsu & Sanford, 2007). In this technique, participants were presented with an open-ended question. In the case of the participants of this research, this question was "What are the competencies of a science teacher with a high level of TPACK?" In the first round, participants were asked to list all competencies they think a science teacher with a high level of TPACK should possess. In the second round, the researcher organized all of the competencies listed by participants and gave them back to participants for review. Participants evaluated all competencies, commented on them, judged their clarity, and identified similar items. In the third round, the researcher eliminated some of the competencies based on participants' views and organized them into a questionnaire. Participants were asked to rate each competency on a 7-point Likert-type scale and write additional comments if there were any. In the fourth round, based on participants' ratings, the interquartile range and median values were calculated for each item. Then, a new questionnaire was prepared for each participant in which these values and participants' prior rating of that item was presented. Participants were told they could change their previous rating after seeing the interquartile range and median values, or they could stick with their initial rating. In the end, the interquartile range and median values were calculated again. If the interquartile range was one or below for an item, it is considered to be agreed by all participants (De Vet et al., 2005). This classroom activity and its results were submitted to an international conference and published as a full-text proceeding.

In week 5, the TPACK game was played. In this game, three-item pools are prepared by the instructor: content pool, pedagogy pool, and technology pool. Students formed three groups, and each group had two random items and one non-random item. For example, one of the groups selected technology and pedagogy randomly from the pools, and they decided on the appropriate content to be taught using that technology and pedagogy. Then, using those items, each group prepared a classroom activity and shared it with the class.

Throughout the *Application* stage of the course, each week, participants were asked to bring their computers, tablets and/or mobile phones to the classroom. During these weeks, they were given a list of technologies to be examined one-by-one. They were also asked to fill out a table where they wrote the strengths, weaknesses, and educational uses of each particular tool. After the evaluation of the technologies was finished, everybody shared their ideas with each other and discussed how each tool could be used in science lessons.

During *Practice* stage, each week, assigned participants performed micro-teachings. During these micro-teachings, all of the participants in the classroom acted like students, and the assigned participant performed the micro-teaching using their third lesson plan. At the end of each micro-teaching, participants receive and give feedback about that micro-teaching.

3.2.4. Revisions between Cycles of Implementation

After the first cycle of implementation, based on preliminary data analysis and participants' feedback (discussed in the results section, see section 4.1.1.3.), no major revisions were made to the course design. The only revision before the second cycle of implementation was updating the list of technologies to be examined during the *Application* stage and removing some of the technologies. Other than that this design was implemented for two semesters with the same course content. The study was ended at the end of the second cycle of implementation.

3.2.5. The Role of the Researcher

I, the researcher of the present study, had been working as a research assistant at Elementary Science Education department for six years at the time of the study. I had been a teaching assistant in many undergraduate and graduate courses during these six years, including science teaching methods, instructional technologies, measurement and assessment, educational research and so on. I was the co-instructor during the practice hours of these courses. In addition, as the teaching assistant, I observed the lectures given by instructors of these courses. Therefore, I had many experiences in teaching at the university and graduate levels.

In the present study, I was the co-instructor of the *Teaching Science with Technology* course. The course had not been offered in the department for years. Just using the original name of the course, I re-designed the course content and activities with the help of my advisor according to the purpose of the present study. During the first meeting, all participants were informed about the study that was being conducted within that course context, and the lectures were co-instructed by a research assistant.

Even if I was responsible for making presentations, organizing course content, track participants' work and assignments, the other instructor of the course attended all class meetings, participated in class discussions, gave feedback, and provided guidance to the participants and myself.

In DBR studies, the researcher undertakes many different roles (Christensen & West, 2018). For this study, I had many roles, including the designer of the course, the instructor of the course, the data collector, and the data analyst. While performing these roles, I tried to remain objective, be sensitive about participants' needs, and put participants' interests first. I always told participants the course was designed for their benefit, and the most important goal of this study was to help them improve their level of TPACK.

3.3. Participants

In this study, both purposive and convenience sampling principles were employed. Convenience sampling is selecting individuals who are easily available to the researcher and can provide data (Fraenkel et al., 2012). Since the students who were enrolled in *Teaching Science with Technology* graduate course were selected as participants, convenience sampling was used. However, all of the students enrolled in the course were not eligible for the present study. Therefore, purposive sampling was used where the researcher used judgment to select participants according to the needs of their study (Fraenkel et al., 2012). Only the students who have a bachelor's degree in elementary science education program were selected for the study since having pedagogical knowledge, and content knowledge about elementary science education is a prerequisite to participate in the present study.

In the first semester (cycle-1) 9 students were enrolled in the course. However, one of them was a chemistry teacher and, therefore, not included in the present study. Another student did not complete all of the required assignments for the course. For this reason, 7 students were asked to participate in the study, and all of them accepted to be a participant voluntarily. In the second semester (cycle-2) 6 students were enrolled in the course. However, one of them was a chemistry teacher and therefore not included in the present study. For this reason, 5 students were asked to participate in the study, and all of them accepted to be a participant voluntarily. In order to protect the privacy of participants, code names were used throughout the text. Table 3.2 presents information about the participants of this study.

Table 3.2

Participants of the Present Study

Pseudonym	Gender	Teaching experience
	Cycle-1	
Nazım	Male	None
Lale	Female	6 months
Tomris	Female	None
Cemal	Male	6 months
Gülten	Female	2 years of tutoring
Özdemir	Male	None
Nilgün	Female	2 years
	Cycle-2	
Didem	Female	None
Turgut	Male	2 years
Umay	Female	None
Birhan	Female	None
Ayten	Female	None

None of the participants had any prior training about technological tools and/or their integration into science lessons. In addition, not all of the participants were working as a teacher; some of them were working as research assistants, some of them were working in different areas, and some of them were only pursuing their graduate degrees at the time of the study.

3.4. Data collection

As Gravemeijer and Cobb (2006) suggested, design-based research requires a comprehensive data set to be able to draw empirically grounded inferences. In the present study, both qualitative and quantitative data collection procedures were employed in both cycles of implementation. Data were collected by means of lesson plans, micro-teachings, interviews, TPACK questionnaires, and written feedback to answer the following research questions.

> RQ1: What were graduate science education students' ideas about *Teaching Science with Technology* course based on T-A-P course design?
> RQ2: Is there a change in graduate science education students' perceived competencies and self-efficacy of TPACK after attending *Teaching Science with Technology* course based on T-A-P course design?
> RQ3: How did graduate science education students' level of TPACK change as they attended *Teaching Science with Technology* course based on T-A-P course design?

In addition, all of the classroom meetings were recorded, and all of the students' work was archived in case they were needed for clarification of findings. Table 3.3 presents information about which data sources were used to answer which research question and the time schedule for data collection.

Table 3.3

Research Questions and Data Sources

Data Sources		Time Schedule
RQ1	Written feedbacks	Weekly feedback: After each lesson
		General feedback: At the end of the semester
	Interviews	At the end of the semester
RQ2	TPACK-Deep scale	1st administration: At the beginning of the course
		2nd administration: At the end of the semester
	TPACK-SeS Scale	1st administration: At the beginning of the course
		2nd administration: At the end of the semester
RQ3	Lesson plans	1st lesson plan: Submitted at the beginning of the course
		2nd lesson plan: Submitted at the end of the *Theory* stage
		3rd lesson plan: Submitted at the end of the *Application* stage
		4th lesson plan: Submitted at the end of the *Practice* stage
	Interviews	1st interview: Conducted after submission of 1st lesson plan
		2nd interview: Conducted after submission of 2nd lesson plan
		3rd interview: Conducted after submission of 3rd lesson plan
		4th interview: Conducted after submission of 4th lesson plan
	Micro-teachings	Performed once during *Practice* stage

3.4.1. Lesson Plans

In the present study, participants prepared four technology integrated lesson plans; one lesson plan at the beginning of the course and three lesson plans at the end of each stage. Since the T-A-P course design was divided into three stages, the change in participants' level of TPACK was measured by lesson plans at the beginning of the semester and at the end of each stage. In the lesson plan format provided to the participants (Appendix B), there were questions to be answered related to the selection of content, pedagogy, and technology. These questions aimed to help the researcher during the data analysis process and understand participants' rationale for combining the selected content, pedagogy, and technology. Participants were told they needed to integrate at least one technological tool into their lesson plans. They were informed that they could choose any science topic from the curriculum, they could use any teaching method, and they could integrate any technological tool. There were no restrictions regarding the selection of content, pedagogy, and technology.

Participants submitted the first lesson plan at the beginning of the course. In the first meeting, the researcher presented the lesson plan format to the participants and informed them they should submit their first technology integrated lesson plan until the first lesson. With this first lesson plan, participants' initial level of TPACK was determined.

The second lesson plan was collected at the end of the *Theory* stage, after participants attended five class meetings related to theoretical principles of the TPACK framework. In those lessons, 12 articles about technology integration into science education, TPACK framework, and preparing technology integrated science lessons were given as reading assignments and discussed in the classroom with the help of instructor presentations, discussion questions prepared by the participants, and additional in-class activities.

The third lesson plan was collected at the end of the *Application* stage after participants attended four class meetings where they actively used and examined various technological tools that can be used in science lessons. In those lessons, participants also discussed the strengths and weaknesses of each tool and how each tool can be integrated into science lessons.

The fourth and last lesson plans were collected at the end of the *Practice* stage, which also was the end of the semester. During this stage, each participant performed a micro-teaching in the classroom using their third lesson plan. After each micro-teaching, participants received feedback from their peers and the researcher. They also wrote a reflection paper about their own performance.

3.4.2. Interviews

In the present study, four semi-structured interviews were conducted with participants within the following week of each lesson plan submission. The purpose of these interviews was to give participants a chance to elaborate on their lesson plan ideas. The duration of each interview was approximately 30 minutes.

The first interviews were conducted at the beginning of the semester. The questions were prepared by the researcher related to participants' lesson plans and their combination of technology, content, and pedagogy. These questions were:

1. In your lesson plan, which criteria did you use to choose the topic?
    - What can other teaching methods be used to teach that topic? Why?
    - What can other technological tools be used to teach that topic? Why?
2. In your lesson plan, which criteria did you use to choose the technology?
    - How does this technology help students learn science topics?
    - What challenged you the most when integrating this technology into your lesson plan?
    - If you need to implement this lesson plan in a classroom, what concerns you about using this technology? What kind of problems can occur?
    - Suppose you are implementing this lesson plan and a problem related to technology occurs. How can you solve this problem?
    - If you were not instructed to integrate at least one technological tool into your lesson plan, would you integrate it on your own?

3. In your lesson plan, which criteria did you use to choose the teaching method?
    - How does this teaching method help students learn science topics?
    - What challenged you the most when using this teaching method in your lesson plan?
    - If you need to implement this lesson plan in a classroom, what concerns you about using this teaching method? What kind of problems can occur?
4. Which element did you choose first; technology, pedagogy, or content? How did these three elements come together in your plan?
5. Is there anything else you wish to add about your lesson plan?

These questions about the lesson plans were used in all of the other interviews. However, in the following interviews, there were some additional questions. In the second interview, participants were asked to compare their first and second lesson plans. In the third interview, there were some additional questions about their micro-teaching performance. In the fourth and last interview, participants were also asked some questions related to course design.

All of the interview protocols were prepared by the researcher. After that, the questions were reviewed by two other researchers experienced in TPACK studies. The questions were revised and reorganized according to their suggestions. In addition, a pilot study was conducted with a Ph.D. student to test the clarity of questions. After the pilot study, the final version of the interview protocols was formed (Appendix C).

3.4.3. Micro-teachings

In the present study, all of the participants performed a 40 min micro-teaching during the *Practice* stage, using their 3rd lesson plan, which they prepared at the end of the *Application* stage. The purpose of these micro-teachings was to give participants a chance to implement a technology integrated science lesson plan and put their newly gained technological knowledge into action. At the end of micro-teachings, each participant receives feedback from their friends. In addition, they wrote a reflection paper about their micro-teaching experience.

3.4.4. TPACK Scales

In the present study, two TPACK scales were used to capture the change in graduate science education students' perceived competencies and self-efficacy of TPACK after attending the *Teaching Science with Technology* course based on T-A-P course design. Data were collected by pre and post-administration of two scales.

Participants' perceived competencies of TPACK were measured by the TPACK-Deep scale developed by Kabakçı-Yurdakul et al. (2012). It is a 33-item 5-point Likert type scale ("I can easily do it", "I can do it", "I can partly do it", "I can't do it" and "I certainly can't do it") composed of four subscales: Design (designing instruction), Exertion (implementing instruction), Ethics (ethical awareness) and Proficiency (innovativeness, problem solving and field specialization). The confirmatory factor analysis conducted by the developers confirmed the four-factor structure of the scale. In addition, the Cronbach's alpha reliability coefficient of subscales ranged between .85 and .92 (Kabakçı-Yurdakul et al., 2012). The internal consistency value for the whole scale was found to be α = .95. In the present study, Cronbach's alpha reliability coefficient values ranged between .92 and .98 for subscales and the whole scale.

Participants' self-efficacy of TPACK was measured by the TPACK-SeS scale developed by Canbazoğlu-Bilici et al. (2013). It is a 52-item 100-point rating scale ranging from 0 (cannot do at all) to 100 (highly certain can do) divided into 10 unit intervals composed of eight subscales: Technological knowledge (TK), pedagogical knowledge (PK), content knowledge (CK), technological pedagogical knowledge (TPK), technological content knowledge (TCK), pedagogical content knowledge (PCK), technological pedagogical content knowledge (TPACK) and knowledge of the context (CxK). The confirmatory factor analysis conducted by the developers confirmed the eight-factor structure of the scale. In addition, the Cronbach's alpha reliability coefficient of subscales ranged between .84 and .94. The internal consistency value for the whole scale was found to be α = .98 (Canbazoğlu-Bilici et al., 2013). In the present study, Cronbach's alpha reliability coefficient values ranged between .91 and .99 for subscales and the whole scale.

Pre-administration of scales was immediately after attending the first meeting before the first class session. Post-administration was at the end of the semester after all participants completed all of the assignments. The scales were converted into google forms, and participants filled them out online.

3.4.5. Written Feedback

Since one of the research questions of the present study was to investigate participants' ideas about T-A-P course design and the *Teaching Science with Technology* course, participants were asked to write feedback about that day's lesson to the online discussion forum in the LMS after each class meeting.

In the *Theory* and *Application* stages, participants were asked to give feedback about (1) What can be done to improve the quality of instruction/discussion/presentation etc.; (2) What was the most effective part of the instruction/discussion/presentation etc. In the *Practice* stage, they were asked to write their ideas about (1) Do you think it is effective for presenters and non-presenters? Why?; (2) What can be done to improve the quality of micro-teaching weeks?; (3) What can you suggest to the presenters (teachers) as an observer (student)?

In addition, at the end of the semester, they were asked to write general feedback about the course. For that feedback, no guiding questions were given. Participants were informed that all comments, positive or negative, about the course design, instruction, activities, assignments, readings, or anything else related to the course were very valuable for the improvement of the course.

3.5. Data analysis

In the present study, both qualitative and quantitative data collection procedures were employed in both cycles of implementation to answer the following research questions:

> RQ1: What were graduate science education students' ideas about *Teaching Science with Technology* course based on T-A-P course design?
> RQ2: Is there a change in graduate science education students' perceived

competencies and self-efficacy of TPACK after attending *Teaching Science with Technology* course based on T-A-P course design?
RQ3: How did graduate science education students' level of TPACK change as they attended *Teaching Science with Technology* course based on T-A-P course design?

Analysis of the data for each research question is explained in the following sub-sections.

3.5.1. Analysis of Data for RQ1

For the analysis of the qualitative data collected by written feedback and interviews, the thematic analysis phases proposed by Braun and Clarke (2006) were used. These phases are: (1) familiarizing with data; (2) generating initial codes; (3) searching for themes; (4) reviewing themes; (5) defining and naming themes; (6) producing the report.

First, all written feedback and related interview transcripts were organized and read carefully to search for emerging codes. Then, by carefully scanning the documents, frequently repeated codes were identified. After that, emerging codes with the highest frequencies were listed, reviewed, and collated into potential themes. When the potential themes were identified, the documents were examined again to refine them. Lastly, all themes were finalized, and the emergent codes were organized under these themes.

3.5.2. Analysis of Data for RQ2

In order to answer RQ2, "Is there a change in graduate science education students' perceived competencies and self-efficacy of TPACK after attending *Teaching Science with Technology* course based on T-A-P course design?", TPACK-Deep scale (Kabakçı-Yurdakul et al., 2012) and TPACK-SeS scale (Canbazoğlu-Bilici et al., 2013) were used. These quantitative instruments were analyzed based on the information provided by the developers of the instruments.

After scoring each instrument and subscales, descriptive statistics were obtained. As inferential statistics, the Wilcoxon Signed Rank Test was used to investigate the change in participants' questionnaire scores before and after taking the course. The Wilcoxon Signed Rank Test is a nonparametric alternative of paired-samples t-test, preferred with small sample sizes and used to identify if there is any change in participants' responses from Time 1 to Time 2 (Pallant, 2011). In addition, individual scores of participants on subscales and whole scales were also calculated and presented.

3.5.3. Analysis of Data for RQ3

The lesson plans prepared by participants were analyzed by using the TPACK Levels Rubric developed by (Lyublinskaya & Tournaki, 2012). The rubric was first developed to assess in-service mathematics teachers' level of TPACK while using TI-Nspire technology to teach algebra. In another study, developers of the rubric change the wording of the rubric to make it usable with all technological tools in both science and mathematics lesson plans (Lyublinskaya & Tournaki, 2014). In the present study, this adapted version is used to assess participants' lesson plans (Appendix D).

The TPACK Levels Rubric has a matrix structure; rows represent TPACK components, and columns represent TPACK levels. TPACK components are identified according to the study of Niess (2005), where the researcher rephrased Grossman's (1989, 1990, 1991) descriptions of central components of PCK to determine the components of TPACK. These components are:

- C1: An overarching conception about the purposes for incorporating technology in teaching subject matter topics.
- C2: Knowledge of students' understandings, thinking, and learning in subject matter topics with technology.
- C3: Knowledge of curriculum and curricular materials that integrate technology in learning and teaching subject matter topics.
- C4: Knowledge of instructional strategies and representations for teaching and learning subject matter topics with technologies.

For each component, participants are rated among five levels of TPACK proposed by Niess et al. (2006); recognizing, accepting, adapting, exploring, and advancing. For each level of each TPACK component, two performance indicators are determined based on previous literature (Goldenberg, 2000; Niess, 2011); one of them describes teacher actions, and the other one describes student actions or digital materials. For example, for the *Recognizing* level of C3 - Curriculum component, the performance indicators are: “Teacher does not use instructional technology for learning mathematics or science” and “Instructional technology if used is not aligned with one or more curriculum goals” (Lyublinskaya & Tournaki, 2014).

Participant scores can range between 0 and 5 for each component. If a lesson plan meets both indicators of the component for a particular level, the component score is an integer; if only one of the performance indicators is met, then participants receive a half-integer score. For example, if both indicators of adapting level are met, the participants receive a score of 3. However, if only one indicator is met, then the participant receives a score of 2.5. After determining the level and score of each component, participants’ overall TPACK level is determined by the lowest score they receive across all of the components. For example, if a participant scores 2 for C1, 2.5 for C2, 3 for C3, and 4 for C4; the participants overall TPACK level will be Accepting (2).

3.6. Trustworthiness of the Study

In qualitative studies, validity issues are discussed under the title of trustworthiness and generally judged by four main criteria suggested by Lincoln and Guba (1985, 1986); credibility, dependability, transferability, and confirmability. To increase the trustworthiness of the present research, various strategies suggested by Merriam (2009) were employed.

Credibility deals with the issue of consistency between research findings and reality (Merriam, 2009). It corresponds to internal validity in quantitative studies In order to establish credibility, *triangulation using multiple methods of data collection* was used. An interview was conducted with participants related to each of their lesson plans to check what was written in plans against what they told in the interviews. Participants' micro-teaching recordings were also used while analyzing third lesson plans. In addition, participants' written feedback about the course design and activities were also triangulated with the interviews. *Triangulation using multiple data sources* was also obtained by collecting data at different points throughout the semester.

Triangulation using multiple investigators was used while analyzing the data. Two other researchers were involved in data analysis and analyzed a portion of the data. Both of them were pursuing a Ph.D. degree and experienced in qualitative data analysis. One of them analyzed a portion of data for written feedback and interviews. The codebook was shared with the researcher, and s/he analyzed three weeks of data for written feedback (one week from each stage of the course) and three of the final interview transcripts. Inter-rater agreement was calculated as 80%. The researchers discussed the differences in coding to solve any conflicts. The other researcher analyzed all four lesson plans of two participants using the TPACK levels rubric. First, the researcher explained how to use the rubric and gave information about the components and criteria included in the rubric. To measure the degree of consistency between two raters, the Pearson product-moment correlation coefficient was calculated and found to be .79.

Adequate engagement in data collection was another strategy employed in this study to increase credibility. The amount of data and the period of data collection depends on the particular study (Merriam, 2009). In the present study, data were collected during two semesters in two cycles. Within each cycle, a significant amount of data was collected by means of four interviews, weekly written feedback, four lesson plans, pre- and post-administration of two TPACK scales, and one micro-teaching. By this way, it was tried to capture participants' progression in detail.

Peer review is another strategy to increase credibility, and all graduate students naturally employ it since the advisor and the committee members monitor the study process and comment on findings (Merriam, 2009).

Reflexivity, which refers to researchers explaining their assumptions, biases, and experiences regarding the study, is another strategy to increase credibility. In section *3.2.4. The Role of the Researcher,* I explained my experiences related to this study and the implemented course. During my graduate education, I have taken courses related to qualitative research, research methods, TPACK framework. In addition, I had experience as a researcher in different projects and research groups related to technology integration into education.

Dependability deals with the issue of consistency between the collected data and results. It corresponds to reliability in quantitative studies. However, replicating a study and yielding the same results is not possible in qualitative research, especially in social sciences. It is not an aim of qualitative research either. For this reason, in qualitative research, a study can be accepted to be dependable if the findings are consistent with the data (Merriam, 2009). To ensure dependability, the use of triangulation, peer review, reflexivity, and audit trail strategies are suggested. The first three strategies were also employed to increase credibility and are explained in the previous paragraphs. The audit trail is "a record of the research process as well as the theoretical, methodological, and analytical choices made by the researcher" (Bowen, 2009, p.307). Using audit trail, researchers can make their decisions clear for readers to follow their logic from data to findings. In the present study, sample excerpts from data were presented to exemplify codes, and the main procedures of lesson plans were described in detail to clarify their assessment. The audit trail also ensures **confirmability** of the study, which corresponds to objectivity in quantitative studies. (Lincoln & Guba, 1986).

Transferability deals with the issue of the generalizability of the findings to other situations. It corresponds to external validity in quantitative studies. To ensure transferability, the most common strategy is to use of rich, thick descriptions (Merriam, 2009). For this reason, detailed descriptions were provided regarding the course design, participants, data collection tools, and findings of the present study.

3.7. Limitations, Delimitations and Assumptions of the Study

Limitations are the potential weaknesses of the study and most of the time beyond researchers' control. In the present study, not all of the participants were actively working as a teacher. Some of them were research assistants, some of them were graduate students, and some of them were working in different areas. This might have influenced their progression during the study. Working as a teacher and having actual classroom experience might be a factor shaping their approach to technology integration.

Another limitation was performing micro-teachings in the context of a graduate course. Since it was not possible for all of the participants to arrange a classroom and get the necessary permissions for practicing implementation of a technology integrated lesson plan, participants performed micro-teachings in the classroom. Having experience teaching with technology in an actual classroom environment might have yielded different results in terms of TPACK development. Moreover, due to time limitations, each participant performed micro-teaching once throughout the course.

In addition, since all of the participants were graduate students at a research-oriented university, it can be inferred that they were all successful graduates of the elementary science education program with strong pedagogical content knowledge. In addition, since the context of the study was a graduate course, they might have put more effort while preparing lesson plans.

Delimitations are the limitations the researcher intentionally put into their research to set the boundaries. In the present study, among the students enrolled in the course, only the ones with a bachelor's degree in elementary science education program were included because it was important for participants to have pedagogical knowledge and content knowledge. It was assumed that all participants had sufficient pedagogical knowledge and content knowledge. The course design was focused on improving technological knowledge and gaining the required skills to combine pedagogy, content, and technology effectively to teach science content.

In addition, the study took place at a single university; the same course design might have different results at a different university. However, the main components and principles of the course design might be informative for other researchers and instructors.

Lastly, it was assumed that participants provided sincere feedback about the course design. The researcher strongly emphasized in all course meetings and interviews that the aim is to improve this design; therefore, constructive criticism is very critical.

3.8. Ethical Considerations

Before data collection, approval was obtained from the Ethical Committee of Middle East Technical University (Appendix E). Participants' permission was also obtained by signed consent forms, which included information about the aim of the study, data collection tools and procedures, and participants' right to leave the study at any point (Appendix F). The real names of the participants were never used in the report, and participants' data were never shared with anybody. During data analysis, when a second researcher analyzed data for reliability, participants' names were kept hidden.

CHAPTER 4

RESULTS

The purpose of this study was to design a graduate course to promote graduate science education students' TPACK development and investigate how graduate science education students' level of TPACK, perceived competencies of TPACK, and self-efficacy of TPACK changed after attending that course. Three research questions guided the presented study. In this chapter, each sub-section presents information about the findings related to each research question. First, participants' ideas about the designed and implemented course are presented. Second, the change in participants' perceived competences and self-efficacy of TPACK is explained. Lastly, the change in participants' level of TPACK throughout the course is presented.

4.1. Findings for Participants' Feedback about T-A-P Course Design

The purpose of this section is to present findings related to the first research question guiding the present study. The question was: "What were graduate science education students' ideas about *Teaching Science with Technology* course based on T-A-P course design?" In order to answer this question, data collected by means of written feedback and interviews were analyzed and discussed in the following sub-sections. Data for each cycle of implementation are presented separately.

4.1.1. Findings for First Cycle of Course Implementation

In this section, findings from seven participants of the first cycle of implementation were discussed using excerpts from written feedback and interviews. All of the weekly feedback posted on the online forum, general feedback written at the end of the semester, and transcripts of the 4th interviews were organized and scanned to identify emerging codes. Most frequent codes were determined and organized under two themes; understanding TPACK and practicing TPACK. Table 4.1 presents these themes and relevant emerging codes.

Table 4.1

Findings for Participants' Feedback about the Course

Themes	Emergent codes
Understanding TPACK	Class discussions In-class activities
Practicing TPACK	Using & learning technologies Performing & observing micro-teachings

4.1.1.1. Understanding TPACK

The analysis of written feedback and interviews revealed that all of the participants frequently mentioned that reading articles assigned throughout the semester, class discussions, and in-class activities were effective and helpful for them in improving their understanding of the TPACK framework. In their written feedback, participants thought the assigned articles and writing reflections about them helped them understand the main concepts and principles of the TPACK framework. Besides reading the articles, discussing them in class with their friends was also found to be very helpful by participants for the development of their TPACK knowledge. Throughout the semester, classroom discussions dominated the lessons; instructors tried to create a discussion environment in all of the lessons. Participants constantly mentioned that classroom discussions were very effective in seeing other viewpoints and forming a better understanding. Some of the participants reported that:

> Lale – Week 2: I think the discussion method is very effective for this course. Because we examined the TPACK framework deeply, also, we discussed the limitations of TPACK this week. By having the discussion, we examine our understanding, and we learn what other friends figure out from the article. We reinforce our learnings together.
>
> Cemal – Week 7: Especially the discussion part of the applications was the most beneficial part because we had a chance to discuss how we can integrate them into science classes and what are the possible strong points or limited sides.

> Tomris – Week 8: Integrating domain free technologies into education is uneasy, and discussing how we can use these technologies in the classes is helpful to concrete their real class use.

Throughout the semester, there were many in-class activities designed to help participants improve their understanding of TPACK. In the *Theory* stage, the activities were mainly related to the TPACK framework; in the *Application* stage, they focused on using, examining, and discussing technological tools; and in the Practice stage, they included performing micro-teachings and acting as students during micro-teachings. These activities were highly demanded and appreciated by the participants. Some comments about these activities made by participants are:

> Nilgün – Week 2: Thanks to different activities, especially when we applied our current understanding related to the integrative and transformation model of TPACK, I could understand the difference between two models more clearly.
> Tomris – Week 5: Discussing authentic learning and practical examples for technology in the classroom that depends on principles of authentic learning were so helpful and effective for concretizing the interdependence aspect of technology, pedagogy, content, and context components. Rather than stating just the name of the activity types, showing specific cases in class is more beneficial for understanding the concept.
> Özdemir – Week 5: Further, this week had an activity, and this activity helped me how to prepare a lesson plan by choosing random technological tools and pedagogy. I think the activity showed that we started to convert our theoretical TPACK to the application of science lessons, and the most effective part was the TPACK game.

All participants expressed positive ideas about course content and activities in terms of helping them understand the TPACK framework. In their general feedback about the course, all participants stated that after taking the *Teaching Science with Technology* course, they gained theoretical knowledge about the TPACK framework with the help of reading articles, classroom discussions, in-class activities, and instructor presentations.

4.1.1.2. Practicing TPACK

Participants' feedback showed that *Teaching Science with Technology* course made them practice TPACK and improve their level of TPACK by using/learning different technological tools and performing/observing micro-teachings. During the *Application* stage of the course, participants learned different technological tools and examined them in class with the guidance of instructors. This stage was found to be both helpful and enjoyable by all participants to improve their technological knowledge. In addition, while examining these tools, participants were also asked to evaluate each tool in terms of its strengths, weaknesses, and educational uses. They expressed that learning, using and examining different technological tools, and discussing their integration into science lessons were effective for their development. Excerpts from participants' feedback are quoted below:

> Gülten – Week 6: I learnt different technologies and how I can use these technologies in lessons this week. We also had a chance to try these technologies, and it was also beneficial and entertaining. I think that this lesson was very beneficial and informative.
>
> Tomris – Week 7: Learning new educational websites and evaluating them are helpful in enhancing our technology, pedagogy, and content knowledge.
>
> Lale – Week 8: This week, we investigate different technological tools. Before this lesson, I have never used some applications such as Facebook, Twitter for educational purposes. Moreover, I have never used and heard the name of some of these applications. With the help of this lesson, I will try to use them. Maybe I will use it next time. I think that learning these applications improves my technological skills.

Participants also found the *Practice* stage of the course considerably helpful and effective. During this stage, each participant performed a micro-teaching in-class and received feedback from their peers and instructors afterward. For most of the participants, it was their first experience of implementing a technology integrated science lesson plan. They frequently mentioned that performing micro-teachings gave them a chance to face the challenges of integrating technology into science lessons. Some of the participants reported that:

> Nazım – Week 10: As a presenter, I had a chance to use what I have learned in this course. Moreover, I understood that this course is useful for the ones who want to develop themselves in technology integration in science classes.
>
> Cemal – Week 11: Micro-teachings are very beneficial for both presenters and non-presenters. Presenters had a chance to experience their technology integrated science lessons, and while presenting, they faced both barriers and strengths of it. Non-presenters also observe the weak and strong points of the different technologies with different pedagogical and contextual usage.

> Özdemir – Week 12: When I am a non-presenter, I try to understand how students have difficulty using technology. As a presenter, I observed the advantages and disadvantages of using technology in the classroom with respect to teacher and students. I realized my lacking part of TPACK.

Overall, participants expressed that throughout the semester, they had many opportunities to put their newly gained TPACK knowledge into action. They stated that with the help of practical classroom activities such as examining technological tools and performing micro-teachings, they had a chance to identify their strengths and weaknesses while using technology in science teaching.

To summarize, participants found the course design effective in learning and practicing TPACK. In the 4th interview, when they were asked whether they would suggest this course to a graduate student or a pre-service teacher, all of them stated that they would suggest this course. Participants mentioned that especially graduate students who wish to study TPACK in their graduate studies should take this course. They also stated that graduate students with a different research interests would also benefit from this course to improve their level of TPACK. For pre-service teachers, all of them stated they would suggest this course since it would be very helpful for their professional development. They also mentioned that this course should be a must-course for pre-service teachers with revisions in the syllabus. They expressed that the course load would be difficult for pre-service teachers to handle. For this reason, they suggested that this course should be offered to pre-service teachers by keeping the content of the course the same and decreasing the number of reading articles and assignments.

4.1.1.3. Suggestions for Improvement of the Course

Since DBR requires at least two or more iterations, and the researcher made necessary revisions to the design based on preliminary data analysis between iterations, after the first cycle of implementation, participants' feedback, responses to TPACK scales, and their lesson plans were analyzed. The details of analyses for TPACK scales and lesson plans are presented in the following sections of this chapter.

In their written feedback and interviews, participants were asked to give feedback about what can be done to improve the quality of the *Teaching Science with*

Technology course. Most of the participants expressed that they were satisfied with the course design and nothing needs to be changed for future semesters. However, there were some suggestions from some of the participants. Their suggestions for revisions included:

- Increasing the number of in-class activities during the Theory stage;
- Presenting some of the technological tools during the Theory stage;
- Decreasing the number of technological tools examined during the Application stage.

These suggestions were assessed by the researcher one by one.

Increasing the number of in-class activities. This suggestion came from two of the participants after the first lesson. In the first week, there was a small in-class activity about defining education. At the end of this lesson, two participants suggested there should be more in-class activities like that. The researcher took this suggestion into consideration and immediately added in-class activities to each week during the *Theory* stage. In both cycles of implementation, each week, there were small in-class activities during the *Theory* stage.

Presenting some of the technological tools during the Theory stage. In their general feedback, two of the participants suggested that some of the technological tools examined during the *Application* stage may be presented during the *Theory* stage. They stated that the *Application* stage was more enjoyable when compared to the *Theory* stage; therefore, adding technology examinations to these weeks may make the *Theory* stage more enjoyable. However, they also said that examining technologies after gaining theoretical knowledge was more effective. Other participants also stated that the sequence of stages was meaningful. They explained that they needed theoretical information regarding technology integration to be able to examine technological tools with an informed perspective. Since there was no consensus among participants about this suggestion, no revisions were made based on this suggestion.

Decreasing the number of technological tools examined during the Application stage. Three participants suggested that during the *Application* stage, some technological tools can be removed from the list of technologies to be examined in order to spend more time on discussion about these technologies. The researcher also observed that in some weeks, the examination of technologies took more time than planned. For this reason, the list of technologies to be examined during the *Application* stage was reviewed, and some of the technologies were excluded from classroom discussions during the second cycle. Even though each week participants were provided with the same list of technologies in both cycles of implementation, some of the technological tools were not examined or discussed in the classroom in the second cycle of implementation. They were just presented to the participants for them to examine in their own time.

Besides participants' feedback, data collected by means of TPACK scales were analyzed, and the results revealed that participants' self-efficacy and perceived competencies of TPACK increased significantly at the end of the first cycle of implementation. In addition, when the first and fourth lesson plans of participants were compared, there was a noticeable improvement in terms of technology integration.

Based on preliminary analyses, it was concluded that the course design was effective in terms of supporting participants' understanding of the TPACK framework, helping participants integrate technology into their lesson plans, and improving their self-efficacy and perceived competencies of TPACK. Participants' feedback also supported these analyses. For this reason, no major revisions were made to the course design before the second cycle of implementation.

4.1.2. Findings for Second Cycle of Course Implementation

In this section, findings from five participants of the second cycle of implementation are presented using excerpts from written feedback and interviews. All of the weekly feedback posted on the online forum, general feedback written at the end of the semester, and transcripts of the 4^{th} interviews were organized and analyzed using the emergent codes and themes (see Table 4.1) obtained while analyzing the data from the first cycle of implementation.

4.1.2.1. Understanding TPACK

Similar to the first cycle of implementation, participants of the second cycle also found weekly readings and class discussions about them effective for their understanding of the TPACK framework. In their written feedback and interview, participants stated that especially during the *Theory* stage of the course discussing the articles with the guidance of instructors helped them understand the theoretical background of technology integration into science education. Some of the participants wrote:

> Umay – Week 1: The lesson was different from my expectations in terms of the discussion part. Actually, I am happy because the discussions in this class are different from the courses I have taken before. In the discussions in those classes, we only discussed the given article instead of a free discussion environment. In other words, we followed those readings step by step in class, but the discussions did not only depend on articles in this class. Therefore, I am so glad not to do that. Additionally, the discussion questions in the class forced me to think about technology integration.
> Birhan – Week 2: Before the lesson, my friends have some questions about the readings. In the lesson, the questions were discussed and answered. This made the issue more clear. In addition, the main points were supported by the presentation. This makes us easy to follow the main points. I think that the most effective part of the lesson was discussing the issue with my classmates and instructors.
> Didem – Week 3: Articles that we read in the 3-week review the literature both in Turkish and in the international context in detail, and in this way, we had a chance to look TPACK framework from a broader perspective. We had a chance to understand the problems of the framework, the areas that need further investigation, and the points that should be carefully considered while studying TPACK. Classroom discussions related to these issues were very beneficial and effective for me.

Participants also mentioned the effectiveness of in-class activities in their feedback frequently. They stated that the classroom activities such as the Delphi study and TPACK game helped them clarify important points related to the TPACK framework. Excerpts from participants' feedback are quoted below:

> Didem – Week 2: The handout that we filled out was very useful. Before coming to the classroom, I had some questions in my mind related to some

> components of TPACK, and I experienced difficulty when considering related examples. In the classroom, firstly, definitions of components were given to us, and then we were asked to find examples regarding this component. We shared our examples and discussed them, and this was the most effective part of the lesson for me.
> Ayten – Week 4: We talked about a Delphi study about TPACK, and our topic is what are the knowledge and skills that the TPACK framework components include for elementary science teachers. In my opinion, the Delphi study helps us to make it clear the TPACK framework in our mind.
> Turgut – Week 5: The most interesting part of the class was the TPACK game part, of course. We made a basic technology integrated activity plan in a short time. Therefore, I am happy to see that we can manage to combine randomly selected pedagogy, randomly selected technology, and content that we selected.

To sum up, participants thought that the selected articles and class discussions about them were effective features of the *Teaching Science with Technology* course in terms of improving their understanding of technology integration into science education and the TPACK framework. In addition, additional in-class activities were appreciated by participants since they increased their participation in lessons and facilitated group work.

4.1.2.2. Practicing TPACK

During the Application stage of the course, participants were presented with various technological tools, examined them on their own, and discussed their integration into the science lesson. Most of the participants mentioned that this stage was helpful for them to get familiar with technology and gain perspective about technology integration. Some of the participants reported that:

> Turgut – Week 6: I found the examples very interesting and informative; I didn't know many of them. Being introduced to such technologies and databases are helpful for us to be familiar with them in our studies and future lesson plans. Also, the rubric made it easier for us to determine the usability of that technology.
> Didem – Week 9: Firstly, the links of the technologies were introduced to us, and then we were given some time to play with the technologies, and this was the most effective part of the lesson for me. I think getting engaged with the technologies by ourselves is more effective than introducing them through direct instruction. Then, we discussed how we could use them in science lessons, their affordances, and their limitations. We were also provided some

> links that included examples about wiki platforms to examine, and I think they were also beneficial for us.
> Ayten – General feedback: Examining of technology part is also a useful part for me because I gain technological self-efficacy by using them. In addition to that, I had a chance to know such a lot of software technologies which are appropriate for science teaching.

In addition to examining technologies, using them in their micro-teachings and observing the performance of their friends were found to be effective by most of the participants. In their feedback, they stated that performing and observing micro-teachings were useful to see their own performance and different examples of technology integrated science lesson plans. Some comments about these micro-teachings made by participants are:

> Birhan – Week 10: All micro teachings were very enjoyable for me. We saw the different technology combinations, different teaching methods, and different subjects.
> Didem – Week 10: Microteachings in this course were really fruitful and enjoyable for me. As we have talked about before, TPACK is unique to teachers, and everybody integrates technologies in different ways, even if they use the same one. We examined many technologies, and it was good to see how these technologies combined with the content and pedagogy in practice.
> Ayten – Week 11: Micro-teaching is a good idea and application to see how to use the technologies which we examine in a real classroom. Examination of technology and application of technology in a classroom are so different.

In short, besides gaining theoretical knowledge about the TPACK framework, getting a chance to actively use technological tools was effective for participants. Similar to the findings of the first cycle of implementation, participants of the second cycle also thought that examining technological tools, discussing their affordances and limitations, and integrating them into their science lesson micro-teachings were useful to practice their newly gained technological pedagogical content knowledge.

4.1.2.3. Suggestions for Improvement of the Course

Participants of the second cycle were also asked to provide suggestions to instructors for improvement of the course. In their feedback and interviews, they did not write any significant suggestions for the lessons; they just gave positive comments about the lessons. In their general feedback and interviews, they again expressed positive ideas. One of the participants, Turgut, wrote:

> "A course like *Teaching Science with Technology* will help and encourage the pre-service teachers or teachers to integrate the technology into their lesson as much as they can. If they take a course like this during school life, they can easily integrate the technology to get a more effective learning environment in their lesson".

Similarly, other participants also mentioned that the organization of stages, class activities, assignments, and course content were effective and meaningful for their improvement. This feedback was repeated during the interviews. Since analyses of TPACK scales and lesson plans also supported this feedback, data collection was ended at the end of the second cycle. The course design was found effective for graduate science education students' development of TPACK according to the feedback and analysis of data.

4.2. Results for the Change in Participants' Perceived Competencies and Self-Efficacy of TPACK

The second research question of the present study was "Is there a change in graduate science education students' perceived competencies and self-efficacy of TPACK after attending the *Teaching Science with Technology* course based on T-A-P course design?". For this research question, data were collected by means of two scales, and data were analyzed using Wilcoxon Signed Rank Test.

The dependent variables were participants' perceived competencies of TPACK and participants' self-efficacy of TPACK. The independent variable was the time of administration; before and after taking the *Teaching Science with Technology* course based on T-A-P course design. The results for each dependent variable are presented for each cycle of implementation in the following sub-sections.

4.2.1. Change in Participants' Perceived Competencies of TPACK

Participants' perceived competencies of TPACK were measured by the TPACK-Deep scale, which is a 33-item 5-point Likert type scale composed of four subscales: Design, Exertion, Ethics, and Proficiency (Kabakçı-Yurdakul et al., 2012). Data were collected by means of pre- and post-administration of the scale before and after attending the *Teaching Science with Technology* course based on T-A-P course design.

For the first cycle of implementation, descriptive statistics revealed that participants' mean scores on all of the subscales and total scale increased after attending the *Teaching Science with Technology* course. Participants' mean scores increased from 3.54 to 4.40 in the design subscale; 3.68 to 4.43 in the exertion subscale; 3.64 to 4.76 in the ethics subscale; 3.43 to 3.97 in the proficiency subscale; and 3.59 to 4.41 in a total of TPACK-Deep scale. Table 4.2 presents descriptive statistics for pre- and post-administration of the TPACK-Deep scale in the first cycle of implementation.

Table 4.2

Descriptive Statistics for TPACK-Deep Scale (Cycle-1)

	Time	N	Mean	SD	Min.	Max.	Range
Design	Pre	7	3.54	.86	2.00	4.60	2.60
	Post	7	4.40	.34	4.00	4.80	.80
Exertion	Pre	7	3.68	.59	2.58	4.33	1.75
	Post	7	4.43	.36	4.00	4.83	.83
Ethics	Pre	7	3.64	.49	3.00	4.50	1.50
	Post	7	4.76	.13	4.50	4.83	.33
Proficiency	Pre	7	3.43	.75	2.20	4.20	2.00
	Post	7	3.97	.68	2.80	4.60	1.80
TPACK competency	Pre	7	3.59	.64	2.42	4.24	1.82
	Post	7	4.41	.31	3.97	4.76	.79

Similarly, participants' mean scores on all of the subscales and total scale increased after attending the *Teaching Science with Technology* course in the second cycle of implementation. Participants' mean scores increased from 4.10 to 4.80 in the design subscale; 4.15 to 4.65 in the exertion subscale; 3.87 to 4.63 in the ethics subscale; 3.64 to 4.24 in the proficiency subscale; and 4.01 to 4.63 in a total of TPACK-Deep scale. Table 4.3 presents descriptive statistics for pre- and post-administration of the TPACK-Deep scale in the second cycle of implementation.

Table 4.3

Descriptive Statistics for TPACK-Deep Scale (Cycle-2)

	Time	N	Mean	SD	Min.	Max.	Range
Design	Pre	5	4.10	.56	3.40	4.80	1.40
	Post	5	4.80	.20	4.60	5.00	.40
Exertion	Pre	5	4.15	.43	3.67	4.83	1.17
	Post	5	4.65	.38	4.08	5.00	.92
Ethics	Pre	5	3.87	.42	3.50	4.50	1.00
	Post	5	4.63	.32	4.17	5.00	.83
Proficiency	Pre	5	3.64	.65	2.80	4.60	1.80
	Post	5	4.24	.46	3.60	4.80	1.20
TPACK competency	Pre	5	4.01	.42	3.42	4.61	1.18
	Post	5	4.63	.30	4.24	4.91	.67

In order to investigate whether the increase in mean scores was statistically significant for subscales and the total scale, Wilcoxon Signed Rank Tests were performed. For both cycles of implementation, Wilcoxon Signed Rank Test revealed a statistically significant increase in design competencies of participants after taking the *Teaching Science with Technology* course, with a large effect size. Table 4.4 presents the results of the test for the design subscale.

Table 4.4

Wilcoxon Signed Rank Test Results for Design Subscale

	Pretest Median	Posttest Median	Z	Sig.	Effect Size
Cycle-1	3.70	4.50	2.37	.02	.63
Cycle-2	4.20	4.80	2.03	.04	.64

The design subscale of the TPACK-deep scale consists of 10 items aiming to assess teachers' perceived competencies related to designing a teaching process with the help of technology. Items in this subscale address the important aspects of the teaching design process, such as analysis of the situation before teaching, selection of appropriate methods and technologies, and preparation of a teaching plan. Example items included in this subscale are:

- I can update an instructional material based on the needs by using technology.
- I can use technology to develop activities based on student needs to enrich teaching and learning process.
- I can combine appropriate methods, techniques, and technologies by evaluating their attributes in order to present the content effectively.

Based on the test results, it can be concluded that participants' perceived competencies related to designing a teaching plan with the help of technological tools had significantly improved after attending the *Teaching Science with Technology* course based on T-A-P course design for both cycles of implementation.

Wilcoxon Signed Rank Test also revealed a statistically significant increase in exertion competencies of participants after taking the *Teaching Science with Technology* course for both cycles of implementation with a large effect size. Table 4.5 presents the results of the test for the exertion subscale.

Table 4.5

Wilcoxon Signed Rank Test Results for Exertion Subscale

	Pretest Median	Posttest Median	Z	Sig.	Effect Size
Cycle-1	3.83	4.58	2.37	.02	.63
Cycle-2	4.08	4.58	2.02	.04	.64

The exertion subscale of the TPACK-deep scale consists of 12 items designed to capture teachers' perceived competencies related to the execution of a teaching process while using technology. Items in this subscale are focused on the active learning process of students and the evaluation of the effectiveness of the teaching process. Example items of this subscale are:

- I can implement effective classroom management in the teaching and learning process in which technology is used.
- I can use technology for implementing educational activities such as homework, projects etc.
- I can use innovative technologies to support the teaching and learning process.

Based on the test results, it can be inferred that participants' perceived competencies related to executing a teaching process in which technology is used significantly improved after attending the *Teaching Science with Technology* course based on T-A-P course design for both cycles of implementation.

For both cycles of implementation, Wilcoxon Signed Rank Test revealed a statistically significant increase in ethics competencies of participants after taking the *Teaching Science with Technology* course, with a large effect size. Table 4.6 presents the results of the test for the ethics subscale.

Table 4.6

Wilcoxon Signed Rank Test Results for Ethics Subscale

	Pretest Median	Posttest Median	Z	Sig.	Effect Size
Cycle-1	3.67	4.83	2.37	.02	.63
Cycle-2	3.83	4.67	2.02	.04	.64

The ethics subscale of the TPACK-deep scale includes six items focusing on teachers' perceived competencies related to ethical issues regarding the teaching profession and technology use in the classroom. Items in this subscale address ethical issues such as equal access, protection of privacy, and copyright issues. Example items covered in this subscale are:

- I can provide each student equal access to technology.
- I can follow the teaching profession's codes of ethics in online educational environments.

Based on the test results, it can be claimed that participants' perceived competencies related to ethical issues regarding integrating technology in their teaching process had significantly developed after attending the *Teaching Science with Technology* course based on T-A-P course design for both cycles of implementation.

According to Wilcoxon Signed Rank Test results, there was a statistically significant increase in proficiency competencies of participants after taking the *Teaching Science with Technology* course for both cycles of implementation with a large effect size. Table 4.7 presents the results of the test for the proficiency subscale.

Table 4.7

Wilcoxon Signed Rank Test Results for Proficiency Subscale

	Pretest Median	Posttest Median	Z	Sig.	Effect Size
Cycle-1	3.40	4.20	2.46	.01	.66
Cycle-2	3.60	4.40	2.02	.04	.64

The proficiency subscale is composed of five items aiming to assess teachers' perceived competencies related to troubleshooting problems that can occur while integrating technology into the teaching process. The items of this subscale focus on becoming an expert and cooperating with others while using technology in teaching. Example items included in this subscale are:

- I can troubleshoot any kind of problem that may occur while using technology in any phase of the teaching-learning process.
- I can become a leader in spreading the use of technological innovations in my teaching community.

Based on the test results, for both cycles of implementation, it can be said that participants' perceived competencies related to their proficiency while using technology in their teaching process had significantly improved after attending the *Teaching Science with Technology* course based on T-A-P course design.

As it was evident from the results regarding subscales, participants' overall perceived competencies of TPACK improved significantly for both cycles of implementation. The developers of the TPACK-Deep scale also suggested the use of total scores for the scale. The minimum score that can be obtained from this scale is 33, and the maximum score is 165. According to the information provided by the developers of this instrument, total scores above 130 corresponds to a high level of TPACK; scores between 95 and 130 correspond to a medium level of TPACK, and scores below 95 correspond to a low level of TPACK. Table 4.8 presents the total scores of each participant from both cycles of implementation before and after taking the course.

Table 4.8

Total Scores of Participants for TPACK-Deep Scale

		Pre-administration		Post-administration	
Participant	Cycle	Total score	Level of TPACK	Total score	Level of TPACK
Nazım	1	80	Low	131	High
Nilgün	1	108	Medium	137	High
Özdemir	1	140	High	157	High
Cemal	1	140	High	151	High
Gülten	1	111	Medium	154	High
Lale	1	123	Medium	152	High
Tomris	1	128	Medium	137	High
Umay	2	113	Medium	146	High
Birhan	2	152	High	162	High
Didem	2	131	High	154	High
Ayten	2	131	High	162	High
Turgut	2	134	High	140	High

All of the participants' total scores increased after taking the *Teaching Science with Technology* course. In the first cycle of implementation, at the beginning of the course, one participant had a low level of TPACK, four participants had a medium level of TPACK, and two participants had a high level of TPACK. At the end of the course, all of the participants had a high level of TPACK. In the second cycle of implementation, at the beginning of the course, one participant had a medium level of TPACK, and four participants had a high level of TPACK. At the end of the course, the participant with a medium level of TPACK also had a high level of TPACK, and the other participants increased their total scores.

4.2.2. Change in Participants' Self-efficacy of TPACK

Participants' self-efficacy of TPACK was measured by the TPACK-SeS scale, which is a 52-item 100-point rating scale ranging from 0 (cannot do at all) to 100 (highly certain can do) divided into 10 unit intervals and composed of eight subscales: Technological knowledge (TK), pedagogical knowledge (PK), content knowledge (CK), technological pedagogical knowledge (TPK), technological content knowledge (TCK), pedagogical content knowledge (PCK), technological pedagogical content knowledge (TPACK) and knowledge of the context (CxK) (Canbazoğlu-Bilici et al., 2013). Data were collected by means of pre- and post-administration of the scale before and after attending the *Teaching Science with Technology* course based on T-A-P course design.

For the first cycle of implementation, descriptive statistics revealed that participants' mean scores on all of the subscales and total scale increased after attending the *Teaching Science with Technology* course. The largest increases were observed in TK (mean difference = 16.46), TCK (mean difference = 18.50), TPK (mean difference = 18.16), TPACK (mean difference = 18.71), and CxK (mean difference = 18.93) subscales. Participants' mean score of overall self-efficacy of TPACK also increased from 75.89 to 89.10 at the end of the course. Table 4.9 presents descriptive statistics for pre- and post-administration of the TPACK-SeS scale in the first cycle of implementation.

Table 4.9

Descriptive Statistics for TPACK-SeS Scale (Cycle-1)

	Time	N	Mean	SD	Min.	Max.	Range
PK	Pre	7	76.02	6.33	64.29	84.29	20.00
	Post	7	87.55	5.39	78.57	92.86	14.29
CK	Pre	7	80.00	8.55	70.00	90.00	20.00
	Post	7	85.24	9.01	76.67	100.00	23.33
PCK	Pre	7	81.21	5.43	71.00	87.00	16.00
	Post	7	88.14	5.68	78.50	94.00	15.50
TK	Pre	7	73.57	17.66	50.00	95.00	45.00
	Post	7	90.03	6.94	81.00	100.00	19.00
TCK	Pre	7	73.57	17.01	45.00	95.00	50.00
	Post	7	92.07	5.08	82.50	97.50	15.00
TPK	Pre	7	72.96	19.37	37.14	95.00	57.86
	Post	7	91.12	3.50	85.71	95.00	9.29
TPACK	Pre	7	71.14	15.36	44.00	88.00	44.00
	Post	7	89.86	5.49	84.00	98.00	14.00
CxK	Pre	7	72.50	16.89	45.00	92.50	47.50
	Post	7	91.43	5.61	81.25	97.50	16.25
Total	Pre	7	75.89	10.75	58.96	88.02	29.06
	Post	7	89.10	4.73	81.77	94.04	12.27

For the second cycle of implementation, descriptive statistics revealed that participants' mean scores on all of the subscales and total scale of TPACK-SeS increased after attending the *Teaching Science with Technology* course. However, the increases were smaller when compared to the increases observed in the first cycle of implementation. The largest increases were observed in TPK (mean difference = 11.71), TCK (mean difference = 7.50), CxK (mean difference = 7.50) and TPACK (mean difference = 13.80) subscales. Participants' mean score of overall self-efficacy of TPACK also increased from 81.67 to 88.23 at the end of the course. Table 4.10 presents descriptive statistics for pre- and post-administration of the TPACK-SeS scale in the second cycle of implementation.

Table 4.10

Descriptive Statistics for TPACK-SeS Scale (Cycle-2)

	Time	N	Mean	SD	Min.	Max.	Range
PK	Pre	5	81.71	9.76	71.43	97.14	25.71
	Post	5	86.71	6.01	77.14	92.14	15.00
CK	Pre	5	83.17	8.63	76.67	97.50	20.83
	Post	5	85.17	5.48	76.67	90.83	14.17
PCK	Pre	5	85.20	9.44	76.00	100.00	24.00
	Post	5	87.80	9.65	73.00	100.00	27.00
TK	Pre	5	78.60	16.55	58.00	98.00	40.00
	Post	5	84.80	6.10	76.00	92.00	16.00
TCK	Pre	5	83.00	12.04	70.00	100.00	30.00
	Post	5	90.50	7.16	82.50	100.00	17.50
TPK	Pre	5	80.00	12.16	65.71	98.57	32.86
	Post	5	91.71	6.18	84.29	100.00	15.71
TPACK	Pre	5	77.20	16.04	60.00	98.00	38.00
	Post	5	91.00	6.86	82.00	100.00	18.00
CxK	Pre	5	81.50	11.12	67.50	95.00	27.50
	Post	5	89.00	7.42	82.50	100.00	17.50
Total	Pre	5	81.67	9.60	71.88	97.71	25.83
	Post	5	88.23	6.03	78.96	94.79	15.83

In order to examine whether the increase in participants' scores was statistically significant for subscales and the total scale, Wilcoxon Signed Rank Tests were performed. For the first cycle of implementation, Wilcoxon Signed Rank Test revealed a statistically significant increase in participants' overall self-efficacy of TPACK after taking the *Teaching Science with Technology* course, $z = 2.37$, $p < .05$, with a large effect size ($r = .63$). When the change in the scores of subscales was examined, the magnitude of difference, measured by effect size, was large in all of the subscales (r value ranged between .59 and .63). Table 4.11 presents the results of the test for subscales and the total scale.

Table 4.11

Wilcoxon Signed Rank Test Results for TPACK-SeS Scale (Cycle-1)

	Pretest Median	Posttest Median	Z	Sig.	Effect Size
PK	75.71	90.00	2.37	.02	.63
CK	80.00	81.67	2.37	.02	.63
PCK	83.50	89.00	2.20	.03	.59
TK	78.00	89.00	2.38	.02	.63
TCK	75.00	92.50	2.37	.02	.63
TPK	81.43	91.43	2.20	.03	.59
TPACK	74.00	90.00	2.37	.02	.63
CxK	67.50	93.75	2.37	.02	.63
Total	79.38	91.25	2.37	.02	.63

On the other hand, for the second cycle of implementation, Wilcoxon Signed Rank Test revealed that the increase in participants' scores on the subscales and the total scale of TPACK-SeS was not statistically significant after taking the *Teaching Science with Technology* course. Table 4.12 presents the results of the test for subscales and the total scale.

Table 4.12

Wilcoxon Signed Rank Test Results for TPACK-SeS Scale (Cycle-2)

	Pretest Median	Posttest Median	Z	Sig.
PK	78.57	87.14	1.48	.14
CK	78.33	86.67	.67	.50
PCK	86.00	88.00	.67	.50
TK	72.00	86.00	.67	.50
TCK	80.00	90.00	1.29	.20
TPK	78.57	90.00	1.75	.08
TPACK	82.00	90.00	1.75	.08
CxK	80.00	87.50	1.63	.10
Total	79.58	87.92	1.75	.08

When each participant's individual scores on pre- and post-administration of the TPACK-SeS scale were examined, it was seen that almost all of the participants' scores increased in all of the subscales and total scale after attending the *Teaching Science with Technology* course. Table 4.13 presents the scores of each participant from both cycles of implementation before and after taking the course.

Table 4.13

Pre- and Post-administration Scores of Participants for the TPACK-SeS Scale

		PK	CK	PCK	TK	TCK	TPK	TPACK	CxK	Total
Cycle-1										
Nazım	Pre	74	70	80	50	45	37	43	52	56
	Post	91	78	86	88	83	91	85	90	87
Nilgün	Pre	63	72	71	55	65	60	63	64	64
	Post	81	78	79	81	89	86	84	81	82
Özdemir	Pre	85	80	78	95	90	86	88	82	86
	Post	89	82	94	98	95	94	98	92	93
Cemal	Pre	74	90	84	95	95	95	88	90	89
	Post	92	93	92	98	96	95	95	93	94
Gülten	Pre	76	85	84	65	65	70	68	70	73
	Post	91	90	94	89	93	91	92	87	91
Lale	Pre	81	90	78	77	80	81	75	66	79
	Post	90	100	89	90	98	93	88	96	93
Tomris	Pre	78	73	85	78	75	81	73	92	79
	Post	79	77	84	83	93	87	85	98	86
Cycle-2										
Umay	Pre	71	78	78	73	70	66	62	76	72
	Post	76	77	73	77	83	84	82	88	80
Birhan	Pre	99	98	100	96	100	99	100	98	99
	Post	91	91	90	88	95	96	95	92	92
Didem	Pre	76	85	86	73	80	79	83	80	80
	Post	84	88	88	87	85	90	88	82	87
Ayten	Pre	79	77	86	55	75	83	83	90	78
	Post	91	83	100	80	100	100	100	100	94
Turgut	Pre	84	78	76	98	90	74	63	68	79
	Post	86	87	88	92	90	89	87	82	87

As it was evident from descriptive and inferential analysis, participants' self-efficacy of TPACK and its components had significantly improved after attending the *Teaching Science with Technology* course based on T-A-P course design for the first cycle of implementation.

On the other hand, for the second cycle of implementation, the increase was not statistically significant. When the individual scores of participants were examined, it was seen that one of the participants from the second cycle, Birhan, had very high scores on pre-administration. Her scores for subscales and the total scale ranged between 96 and 100. Her post-administration scores were also very high and ranged between 88 and 96; however, due to the small sample size, this decrease affected the results of the inferential statistics.

4.3. Findings for the Change in Participants' Level of TPACK

The third research question of the present study was "How did graduate science education students' level of TPACK change as they attend *Teaching Science with Technology* course based on T-A-P course design?". In order to answer this research question, data collected by means of four lesson plans were analyzed using the TPACK levels rubric developed by Lyublinskaya and Tournaki (2012; 2014) and documented for each cycle of implementation in the following sub-sections.

4.3.1. Participants' TPACK Level at the Beginning of the Course

Participants of the present study submitted their first lesson plans at the beginning of the semester, before the first lesson. They were instructed to integrate at least one technological tool into their lesson plans to teach a science topic. They were told they could choose grade level, topic, objectives, teaching methods, and technological tools freely as long as they stayed within the boundaries of the National Science Curriculum.

4.3.1.1. Assessment of First Lesson Plans (Cycle-1)

This section presents findings related to the first lesson plans of first cycle participants. The main activities of the plans and their assessment were explained to each participant separately. The content, pedagogy, and technology used by participants of the first cycle in the first lesson plans are presented in Table 4.14.

Table 4.14

Main Components of Cycle-1 Participants' First Lesson Plans

Participant	Content	Pedagogy	Technology
Lale	Light & shadow	Demonstration	Flashlight of mobile phone
Nazım	Proteins	Laboratory work	Video call program
Tomris	Gas pressure	Demonstration	Video
Gülten	Electric circuits	Analogy	Simulation
Özdemir	Factors affecting the brightness of a lamp	5E – Learning cycle	Simulation, video, camera, and smart board
Cemal	The cell	Learning cycle	Mobile application, online game
Nilgün	Floating and sinking objects	Argumentation	Simulation

Lale's first lesson plan was scored at the *Recognizing (1)* level for all components of the TPACK levels rubric because it did not integrate any technological tools for teaching or learning the subject matter (Figure 4.1). In her lesson plan, the teacher explained the topic of light and shadows using the demonstration method. For technology integration, the teacher used the flashlight feature of a mobile phone during the experiment to create shadows. There were no instructional technologies to be used for subject matter development, presentation of information, student practice, or any other teaching or learning purpose. Technology was just used as a practical tool to replace a flashlight. In the interview, she expressed that "I implemented this plan before in my classroom in the same way. Using a flashlight, I helped students observe shadows". She considered the flashlight as an instructional technology to teach science content even though it has been considered to be a transparent technology for many years.

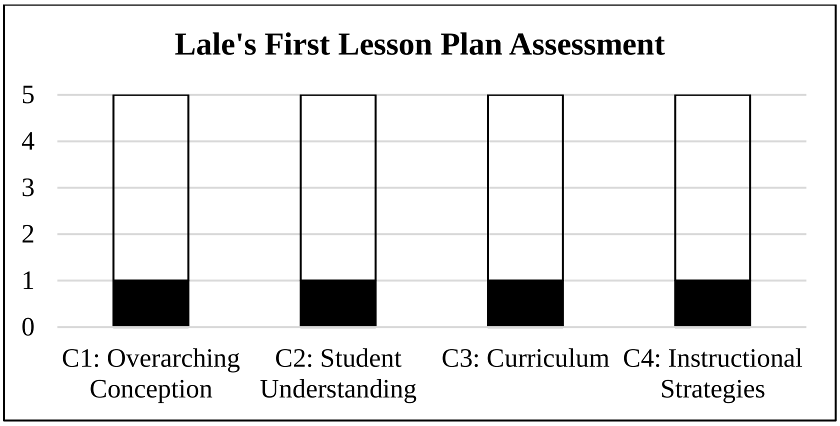

Figure 4.1 Lale's First Lesson Plan Assessment

In Nazım's first lesson plan, most of the lesson was conducted without the integration of any technological tool. Using laboratory work as the teaching method, students learned about proteins and did an experiment with food containing proteins using nitric acid as an indicator. As technology integration, using a video call program, the teacher connected three experts to the classroom after the experiment, and they shared information about proteins. Then, students asked questions to those experts if they had any. In this plan, technology was mainly used for motivational and practical purposes by the teacher. Students did not use technology on their own for learning. For this reason, this lesson plan was scored at the *Recognizing (1)* level for *C2-Student Understanding* and *C4-Instructional Strategies* components of the TPACK levels rubric (Figure 4.2). Since the technology was used as an add-on to standard approaches of teaching and the use of technology allowed presenting new knowledge from experts, this plan met one criterion from the *Accepting (2)* level of *C1-Overarching Conception* and *C3-Curriculum* components and scored as transitioning from *Recognizing* to *Accepting (1.5).* In the interview, when asked about why he chose this technology, Nazım expressed that "I used it to involve experts in the classroom. Without technology, it would be difficult to connect experts with students". He did not give any reasons related to teaching and learning. He explained that he used it for practical and motivational purposes. He also stated that he would not use any technological tools while teaching this lesson plan if it was not a requirement of the course.

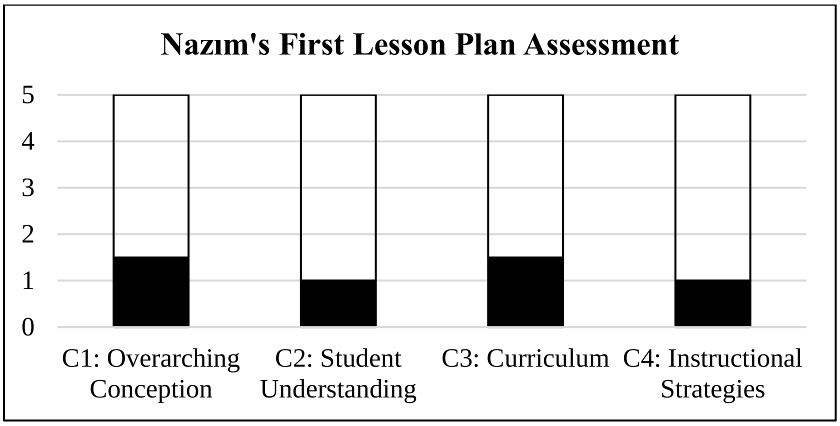

Figure 4.2 Nazım's First Lesson Plan Assessment

Tomris used the demonstration method to teach about gas pressure by performing an experiment to the students in her first lesson plan. Most of the lesson was conducted without the integration of technology. At the end of the demonstration and classroom discussion about the observations and conclusions related to the experiment, students watched a video about the topic summarizing the main points. In this lesson plan, technology was mainly used for motivational purposes rather than actual subject matter development. There were no inquiry activities with technology, and technology was just used for summarizing the topic. For these reasons, this lesson plan was scored as transitioning from *Recognizing* to *Accepting (1.5)* for *C1-Overarching Conception* and *C4-Instructional Strategies* components (Figure 4.3). In addition, digital materials mirrored the structure of the textbook presentation, there were no independent student explorations, technology was used as an add-on to standard approaches of curriculum, and the instruction was teacher-led. Therefore, this lesson plan was scored at the *Accepting (2)* level for *C2-Student Understanding* and *C3-Curriculum* components. In the interview, she stated that “I wanted to use a simulation for student explorations, but I could not find anything appropriate. For this reason, I thought at least I can use a video, and that is why I used it”. She did not try to make students more active while watching the video or find other technological tools that might make the lesson more student-centered.

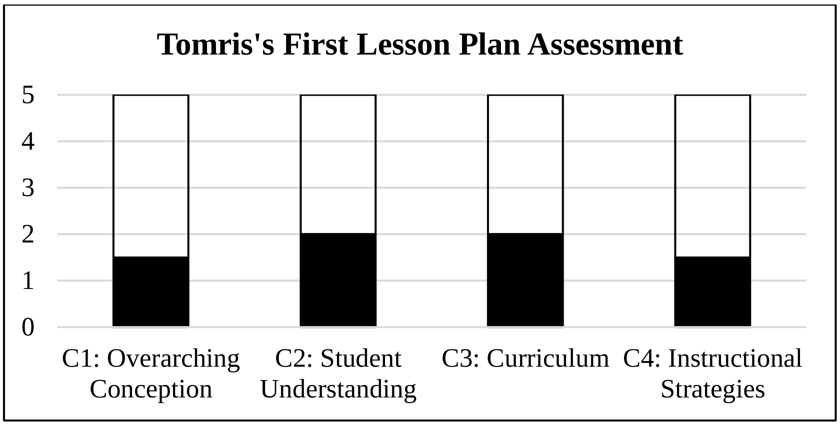

Figure 4.3 Tomris's First Lesson Plan Assessment

In her first lesson plan, Gülten used the water circuit analogy to teach students about electric circuits. Most of the lesson was conducted without using any technological tool. The teacher explained the topic via direct instruction using an analogy. After teaching the topic, the teacher opened a simulation on the smart board to review the concepts and the relationship between voltage, current, and resistance. In this plan, technology was only used by the teacher for demonstration as an add-on to standard approaches of teaching. Even though digital materials provided an environment to do science and aligned with curriculum goals, they were only used for teacher demonstrations, and students did not have a chance to actively and/or independently use technology to explore the topic. For these reasons, this lesson plan was scored as transitioning from the *Accepting to Adapting (2.5)* level for *C2-Student Understanding* and *C3-Curriculum* components. Since there were no inquiry tasks for students and all instructions were teacher-led, this plan was scored at the *Accepting (2)* level for *C1-Overarching Conception* and *C4-Instructional Strategies* components (Figure 4.4). In the interview, she justified her reason for using this simulation as "I used this simulation because it helps students understand the relationships between variables better. When I manipulate the variables, the students can see how other variables change". Even though she was aware of the affordances of the simulation she selected, she did not use them effectively in her lesson plan.

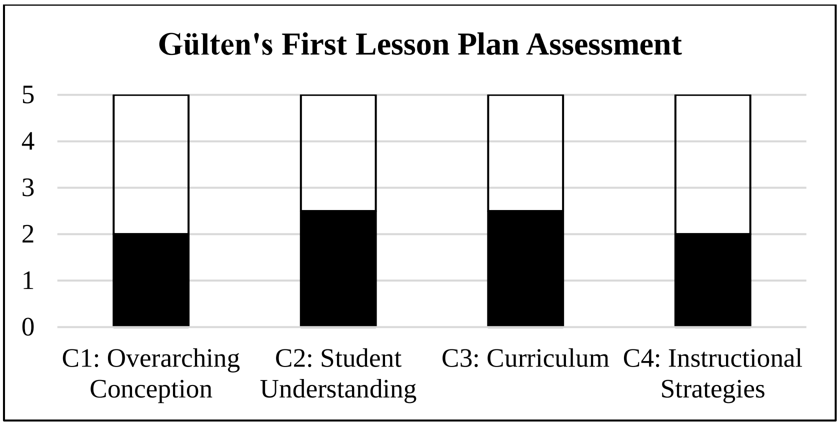

Figure 4.4 Gülten's First Lesson Plan Assessment

Özdemir's first lesson plan included the use of a simulation, a video, a camera, and a smart board. Using the 5E learning cycle teaching method, the topic of factors affecting the brightness of a lamp was taught. At the beginning of the lesson, students performed an experiment by setting up an electric circuit and manipulating the related variables. The teacher used the camera to record the experiment to upload it to an online video streaming platform afterward. The teacher guided students to draw conclusions and made connections at the end of the experiment. For elaboration, the teacher opened a simulation on the smart board, and volunteer students repeated the same experiment on the simulation. The teacher also showed a short video about the topic at this point. Since there were no inquiry tasks for students, the integration of technology was teacher-led, and technology was mainly used for demonstrations, this lesson plan was scored at the *Accepting (2)* level for *C1-Overarching Conception* and *C4-Instructional Strategies* components (Figure 4.5). For *C2-Student Understanding* and *C3-Curriculum* components, this plan was scored as transitioning from *Accepting* to *Adapting (2.5).* Even though digital materials provided an environment for students to do science, technology was not used for independent student explorations. They just followed the steps demonstrated by their teacher. In addition, selected technologies were aligned with curriculum goals, but mostly standard approaches were used for teaching the topic, and technology was used as an add-on. In the interview, when asked about why he used those technologies, he expressed that "I used smart board for motivational purposes, to attract students' attention. I used simulation for practice purposes; students can replicate what they did in the experiment, so they learn the topic better". In his plan, he taught the topic the way he felt comfortable and used technology as an add-on.

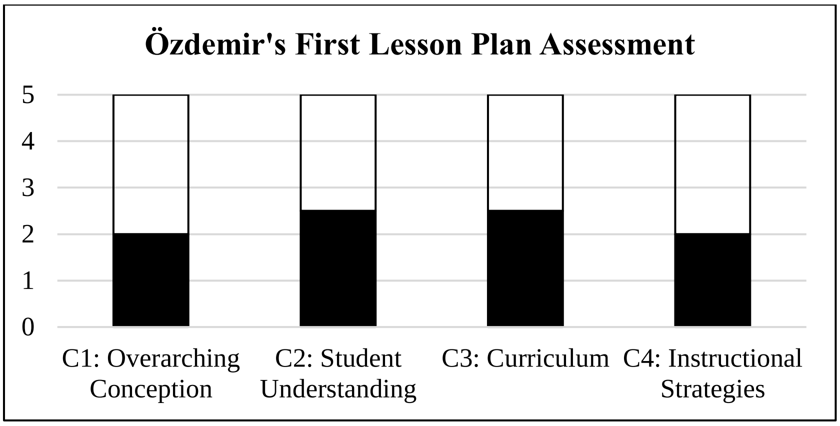

Figure 4.5 Özdemir's First Lesson Plan Assessment

The first lesson plan of Cemal included the integration of a mobile application about the cell and organelles. The learning cycle with three phases was used as the teaching method. At the beginning of the lesson, students' prior knowledge about the main parts of the cell was checked. Then, students were instructed to investigate the eukaryotic cell model and organelles presented in the application. Then, after students learned about the organelles, the teacher introduced a matching activity on the board in which students matched organelles with their functions. Then, the teacher concluded the topic and opened an online game for assessment in which students were asked to label organelles and explain their functions. In this plan, technology was mostly used by students to explore the topic and learn new information. For this reason, this plan met one of the criteria of the *Exploring (4)* level of *C1-Overarching Conception* component and was scored as transitioning from *Adapting* to *Exploring (3.5)*. For all of the other components, this lesson plan was scored at the *Adapting (3)* level because digital materials did not allow students to take actions and observe the consequences. Technology based tasks were used as a replacement for traditional curriculum approaches, the students used digital materials to learn new information with teacher guidance, and the teacher controlled the progression of the activities (Figure 4.6). In the interview, Cemal stated that “I selected these technologies to visualize abstract concepts. I implemented this exact plan in my classroom, but the students needed too much guidance from me. They had difficulties when using the application on their own. I had to guide them when using these technologies on their own regarding what they should look for, how to use the application etc.”. Since he implemented this lesson plan in his actual classroom, he was aware of the problems that might occur and constructed his plan accordingly to have more teacher guidance and direction.

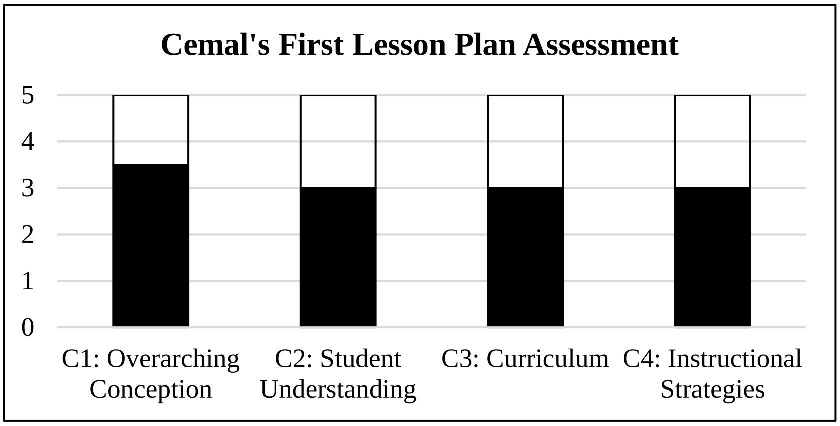

Figure 4.6 Cemal's First Lesson Plan Assessment

Nilgün chose floating and sinking of the objects as the topic to be taught and used inquiry-based learning as the teaching method. At the beginning of the lesson, the teacher asked students what makes an object float or sink in a particular liquid. Then, students formed groups and were introduced to a simulation where they could change the mass, volume, and density of objects and liquids to explore floating and sinking. The teacher guided each group to form different research questions. Students formed hypotheses, made observations, and collected data using the simulation on their own. They determined their own method for investigating their research question. At the end, a student from each group shared their results and conclusions with the class. After students’ explanations and discussion, the teacher summarized the topic and concluded the lesson. In this lesson, students were the primary user of the technological tools to explore a new topic. Technology-based tasks were inquiry-based, and the teacher acted as a guide when they were experimenting with the technology. The teacher successfully taught curriculum objectives with the help of technology. For these reasons, this lesson plan was scored at the *Exploring (4)* level for all components of the TPACK levels rubric (Figure 4.7). In the interview, Nilgün mentioned that "I selected this technology to make students collect data, make observations and draw conclusions. It would be difficult to do this activity with materials in a classroom environment". She was able to identify an appropriate technology to enrich her teaching and go beyond traditional approaches.

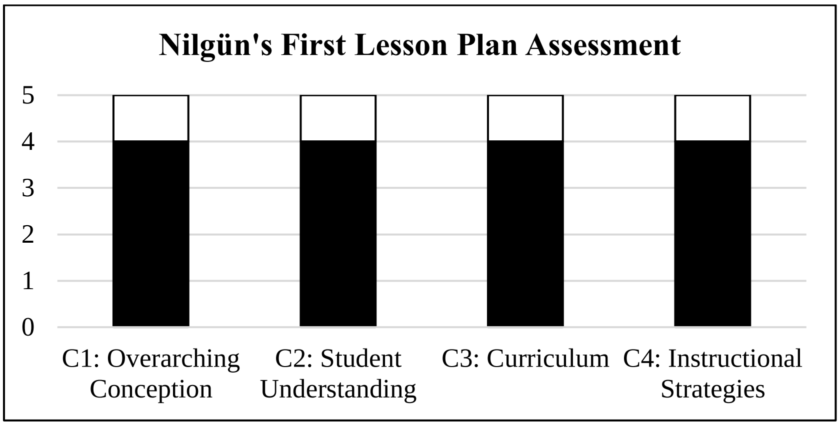

Figure 4.7 Nilgün's First Lesson Plan Assessment

Most of the first lesson plans submitted by the first cycle participants were scored at the *Recognizing* and *Accepting* levels across components of the TPACK levels rubric. None of the lesson plans were scored at the *Advancing* level (the highest level of the rubric) for any of the components. *Exploring* was the highest level of scoring achieved across the first lesson plans. Table 4.15 presents the assessment of the first lesson plans across the components of the TPACK levels rubric for all participants of the first cycle of implementation.

Table 4.15

Assessment of the First Lesson Plans (Cycle-1)

Participant	C1: Overarching Conception	C2: Student Understanding	C3: Curriculum	C4: Instructional Strategies
Lale	1.0	1.0	1.0	1.0
Nazım	1.5	1.0	1.5	1.0
Tomris	1.5	2.0	2.0	1.5
Gülten	2.0	2.5	2.5	2.0
Özdemir	2.0	2.5	2.5	2.0
Cemal	3.5	3.0	3.0	3.0
Nilgün	4.0	4.0	4.0	4.0

4.3.1.2. Assessment of First Lesson Plans (2nd Cycle)

In this section, findings related to the first lesson plans of second cycle participants are explained. The content, pedagogy, and technology used in the first lesson plans by participants of the second cycle of course implementation are presented in Table 4.16.

Table 4.16

Main Components of Cycle-2 Participants' First Lesson Plans

Participant	Content	Pedagogy	Technology
Umay	Sound waves	Direct instruction	Audio editor
Birhan	Moon phases	Learning cycle	Animation
Turgut	Food chain	Discovery learning	Animation, online game
Didem	The cell	Analogy	Simulation
Ayten	Genotypes & phenotypes	5E – Learning cycle	Animation, simulation

Umay used direct instruction and questioning to teach students about the properties of sound and sound waves. The topic was explained by the teacher without the integration of technology. After the teacher explained the important concepts and characteristics of sound, students were divided into groups and used sound editing software on computers to investigate the concepts they learned. They investigated the soundwaves for different sounds. Then, a classroom discussion was held about their observations and conclusions. In this plan, most of the new information was taught beforehand via direct instruction. Students used technology on their own with the guidance of their teacher to practice newly learned information. For this reason, this plan was scored at the *Adapting (3)* level for *C2-Student Understanding* component (Figure 4.8). For all of the other components of the rubric, this lesson plan was scored at the *Accepting (2)* level because the technology was mostly used as an add-on to traditional approaches of teaching for practice and motivation purposes. It is partially aligned with the curriculum, there were no inquiry activities for students, and the instructions were teacher-led. In the interview, she stated that "This technology helps students visualize the properties of soundwaves, that's why I used it. But if it was not a course requirement, I would not probably use this technology to teach this topic". As she mentioned, she just used technology as an add-on because it was a course requirement.

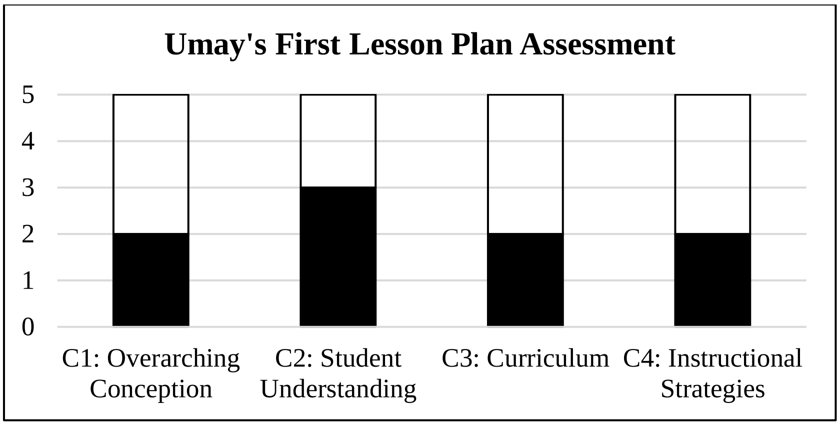

Figure 4.8 Umay's First Lesson Plan Assessment

Birhan used the learning cycle method to teach about the phases of the moon. First, she used a concept cartoon to help students think about how and why there are different phases of the moon. Then, the teacher asked students to form a hypothesis about this phenomenon. Using a V diagram, students answer some questions about the phases of the moon. Then, the teacher used animation to show students how the phases of the moon occur and asked students some questions about this phenomenon. In this lesson plan, the teacher was the primary user of the technology to visualize the topic, and there was no room for student explorations. The instructions were teacher-led, and technology was just used for demonstration. Students made observations under the guidance of their teacher, and there were no explorations with technology. Technology was used as an add-on to the standard approaches of teaching. Therefore, this plan was scored at the *Accepting (2)* level for all components (Figure 4.9). In the interview, Birhan stated that "I used an animation because it would be difficult to teach the phases of the moon with a model. Technology helps students observe the positions of the moon, sun and earth easily". She used technology to support her teaching process; however, the plan was mostly teacher-directed.

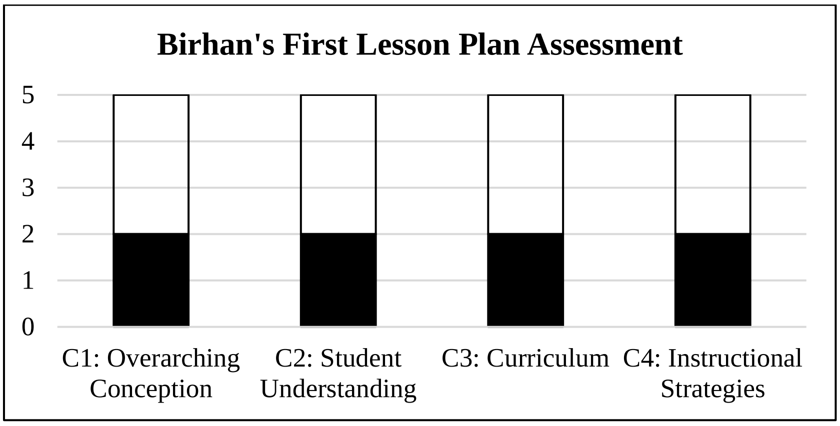

Figure 4.9 Birhan's First Lesson Plan Assessment

Turgut used discovery learning to teach students about food chains. First, the students used animation to learn about food chains and important terms such as consumers, producers, and decomposers. Then, students formed groups and used an online game to construct different food chains. Then, the teacher introduced the concepts of the food web and food pyramid, and students continued to use the online game to learn more about these concepts. In this plan, students used technology to learn new concepts on their own with the guidance of their teacher; however, the nature of the selected technologies did not allow them to ask their own questions to investigate. Technology-based activities were similar to tasks based on traditional approaches. For these reasons, this plan was scored at the *Adapting (3)* level for *C1-Overarching Conception* and *C3-Curriculum* components of the TPACK levels rubric (Figure 4.10). For *C2-Student Understanding* and *C4-Instructional Strategies* components, this plan was scored as transitioning from *Accepting* to *Adapting (2.5)* because the nature of the technological tools selected did not allow students to do active explorations. In the interview, Turgut stated that “The online game did not allow students to make any mistakes while they are constructing the food chains. It only allows students to drag correct animals to their correct position on the food chain, but I could not find a better tool”. Even though he was aware of the limitations of the technology he chose, he still used it in his plan.

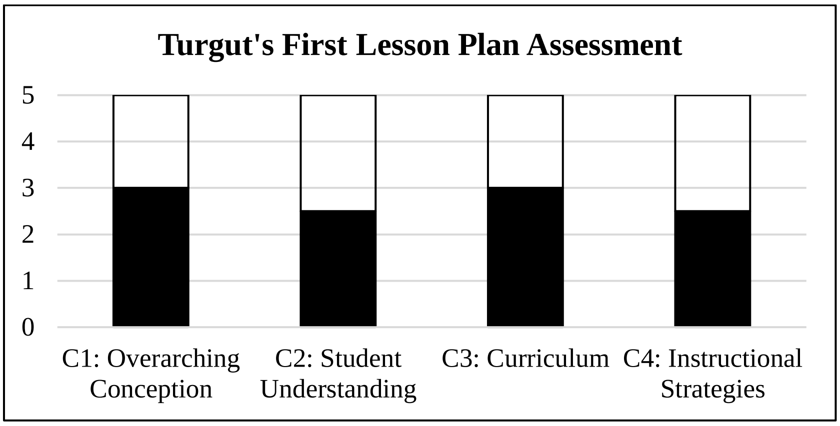

Figure 4.10 Turgut's First Lesson Plan Assessment

Didem also selected the topic of the cell and its organelles to teach using analogies. The lesson started with students filling out a KWL chart to identify what they already knew about the cell and what they wanted to learn. Then, the teacher shared a link of a simulation with students, which allowed students to learn about the cell and its organelles and observe the differences between animal and plant cells. After students completed their exploration, the teacher opened an online game on the smart board and asked students to label the organelles of animal and plant cells. At the end of the lesson, the students were expected to create a cell analogy working in groups and share their work with their friends on the online classroom group. Since, in this plan, students were the primary user of the technology to learn new information and exploration, one of the criteria of *Exploring* level was achieved, and this plan was scored as transitioning from *Adapting* to *Exploring (3.5)* for *C1-Overarching Conception* component (Figure 4.11). *Adapting (3)* level was achieved for the other components since the technology was used as a replacement for non-technology based activities, and digital materials were used by students to learn new information. However, digital materials did not allow students to take actions and observe the consequences. In the interview, Didem mentioned that "I selected this simulation to make the lesson more student-centered. Because this topic is generally taught by direct instruction, and students tend to memorize the information. This simulation helped them construct their own knowledge". She tried to make her lesson more student-centered with the help of technology; however, due to the nature of the topic chosen, technology-based activities were mostly a replacement for traditional classroom activities. They did not allow students to ask questions to explore.

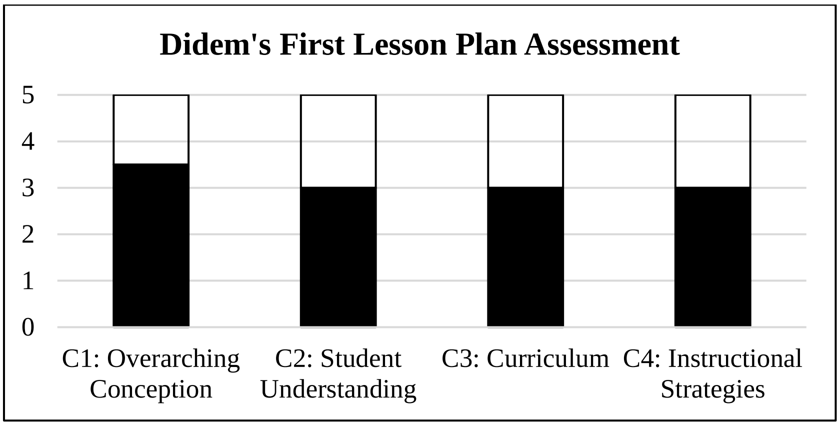

Figure 4.11 Didem's First Lesson Plan Assessment

Ayten selected the topic of genetic heritage to teach with the 5E learning cycle teaching method. After reviewing the previously learned concepts, the teacher started the lesson by showing an animation to students about parents and offspring. She made an introduction using animation. Then, students formed groups to investigate how genotypes and phenotypes of offspring were determined using a simulation. In the simulation, there are different scenarios available for students to explore. The teacher made sure each group investigated a different scenario so that at the end of the activity, students could learn from each other's investigations. Using the simulation, students made observations and calculations to collect data. After all groups finished their investigations, each group presented their observations and conclusions to the whole class. This lesson plan was scored at the *Exploring (4)* level for *C3-Curriculum* component of the TPACK levels rubric (Figure 4.12) because the teacher changed the way this topic is traditionally taught and selected a technology aligned with curriculum goals. For other components, this plan was scored as transitioning from *Adapting* to *Exploring (3.5)* because even though students used technology on their own to learn new information via inquiry-based learning, the activities presented by the simulation were too prescribed. The simulation told students what to do at each step. The teacher controlled the progression of the activities using the simulation. In the interview, Ayten mentioned that “The content of the technological tools are the most important thing for me while selecting a technology. The ones I used include all important information about this topic. These technologies are effective both for teachers and students”. She was able to identify an appropriate technology to make her students explore science ideas in a way that was not possible without technology.

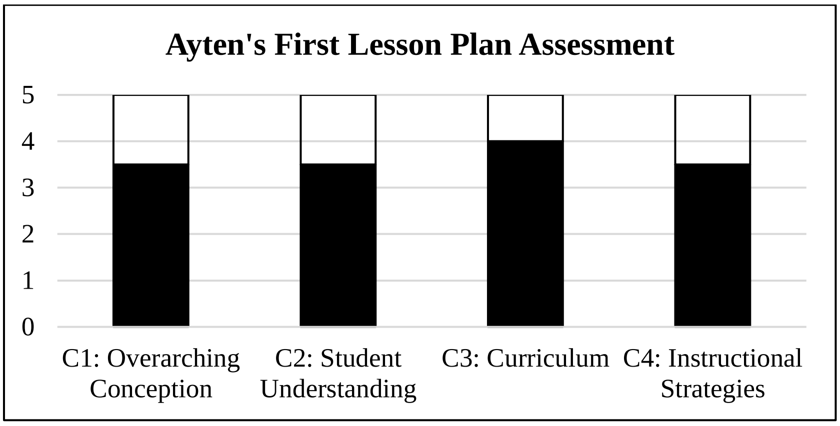

Figure 4.12 Ayten's First Lesson Plan Assessment

Most of the first lesson plans submitted by the second cycle participants were scored at the *Accepting and Adapting* levels across components. None of the lesson plans was scored at the *Advancing* level (the highest level of the rubric) for any of the components. *Exploring* was the highest level of scoring across the first lesson plans, which was achieved by one participant only for one of the components. Table 4.17 presents the assessment of the first lesson plans across the components of the TPACK levels rubric for all participants of the second cycle.

Table 4.17

Assessment of the First Lesson Plans (Cycle-2)

Participant	C1: Overarching Conception	C2: Student Understanding	C3: Curriculum	C4: Instructional Strategies
Umay	2.0	3.0	2.0	2.0
Birhan	2.0	2.0	2.0	2.0
Turgut	3.0	2.5	3.0	2.5
Didem	3.5	3.0	3.0	3.0
Ayten	3.5	3.5	4.0	3.5

4.3.1.3. Summary of the Findings for First Lesson Plans

Participants' overall TPACK level is determined by the lowest score they receive across the components of the TPACK levels rubric. Figure 4.13 presents the distribution of participants from both cycles across different levels for the components of the TPACK levels rubric and overall TPACK level.

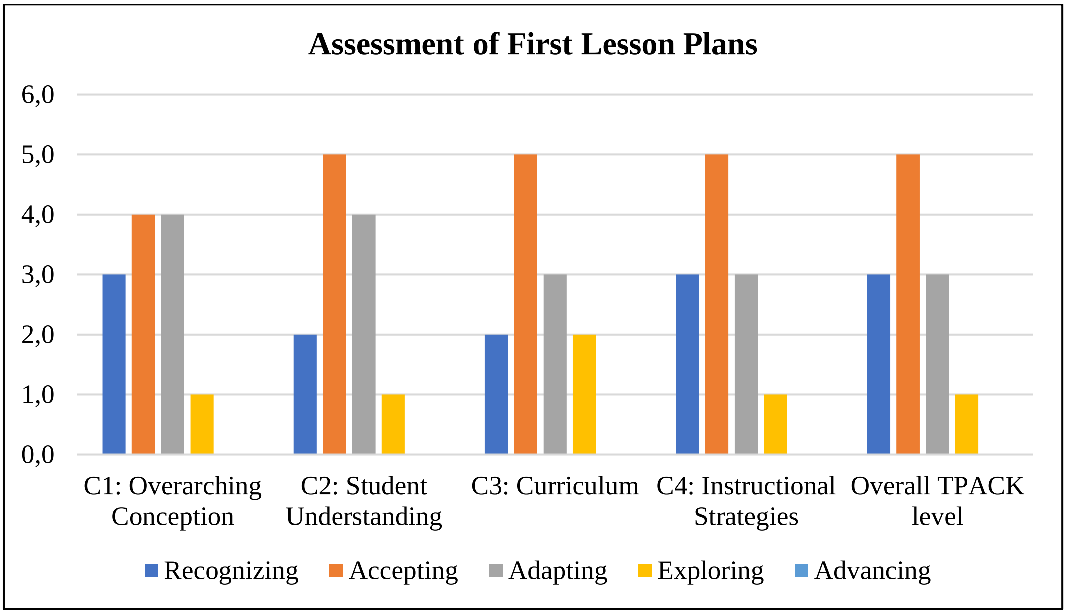

Figure 4.13 Assessment of Participants' First Lesson Plans

In the present study, five participants' (Gülten, Özdemir, Umay, Birhan, and Turgut) overall TPACK was at the *Accepting* level. The teachers at this level mostly use technology for teacher demonstrations and student practice. Technology-based activities at this level do not include inquiry-based tasks or independent student explorations. Even if digital materials are aligned with curriculum goals, they generally represent a textbook structure and are mostly used as an add-on to traditional classroom activities. In their first plans, most of these participants used technology after the topic was taught with traditional methods. Even if, in some cases, students used technology on their own, there were no independent explorations of the topic with technology. Most of the time, technology was used to introduce concepts or practice.

Three of the participants' (Lale, Nazım, and Tomris) overall TPACK was determined to be at *Recognizing* level. At this level, technology is mostly used for motivational purposes instead of subject matter development. Technology is not used for learning any new materials; it only provides opportunities for drill and practice. Participants at this level did not use technology for subject matter development. The teacher was the only user of the technology in their plans for motivational and practical purposes.

Three participants' (Cemal, Didem, and Ayten) overall TPACK was at the *Adapting* level. Teachers at this level try to adapt technologies to their classrooms but do not give up control. Technology-based activities are teacher-directed. Even though students use technology for explorations, they are limited and restrained by their teachers and/or technology. Students cannot develop their own strategies to explore the topic using technology.

There was one participant (Nilgün) whose overall TPACK level was at the *Exploring* level. At this level, technology-based tasks include inquiry activities where students are required to ask questions and use technology to answer those questions. Teachers act as a guide during students' independent explorations. Traditional classroom activities are modified and enhanced with the help of technology. Students use technology on their own to form the hypothesis, collect data and draw conclusions. Students construct their own knowledge with the help of technological tools and activities presented by their teacher.

4.3.2. Participants' TPACK Level at the End of the Theory Stage

Participants submitted their second lesson plans at the end of the *Theory* stage of the course after they attended five course meetings about technology integration into science education and the TPACK framework. During these weeks, it was aimed to help participants gain solid theoretical knowledge to be able to design pedagogically meaningful learning materials with the integration of technology for science teaching. Participants selected the components of their lesson plans freely.

4.3.2.1. Assessment of Second Lesson Plans (Cycle-1)

This section presents findings related to the second lesson plans of first cycle participants. The main components of the second lesson plans selected by participants are presented in Table 4.18.

Table 4.18

Main Components of Cycle-1 Participants' Second Lesson Plans

Participant	Content	Pedagogy	Technology
Lale	Photosynthesis	Cooperative learning	Powerpoint
Nazım	Carbohydrates	POE & Discussion	Simulation
Tomris	Liquid pressure	POE	Simulation, online quiz
Gülten	Skeletal system	Demonstration	Mobile application
Özdemir	Celestial bodies	5E – Learning cycle	Computer program, videos
Cemal	Moon phases	5E – Learning cycle	Simulation
Nilgün	Thermal conductivity	Inquiry-based learning	Web-based science lesson

Lale used cooperative learning and experimenting to teach the topic of photosynthesis. Students performed an experiment about the effect of light on photosynthesis. They made observations and collected data for a period of time. After that, they created a PowerPoint presentation to present their results. Since, in this plan, technology was just used as a practical tool to help students share their results, was not used for teaching and learning purposes, and did not contribute to students' understanding of science ideas, this plan was scored at the *Recognizing (1)* level for all components of the TPACK levels rubric (Figure 4.14). In the interview, Lale stated that "Finding different technological tools is the most difficult part for me. This activity would have been better if students were able to speed up the experiment and see the results immediately". She also confirmed that technology could have been used very effectively to teach this topic; however, she was not able to do that in her plan.

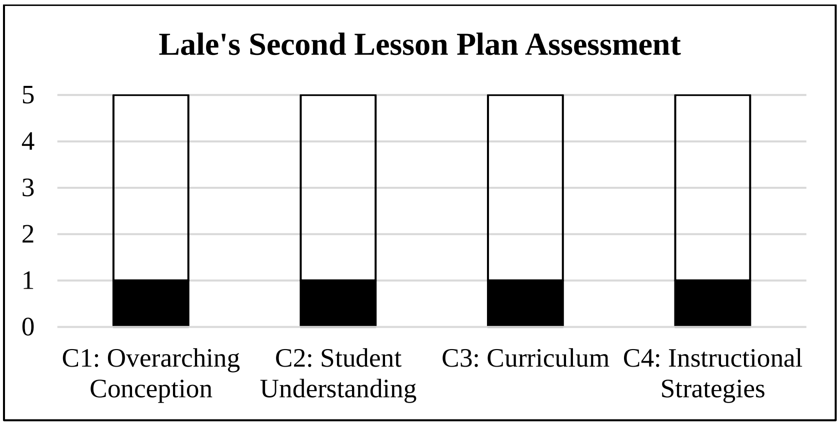

Figure 4.14 Lale's Second Lesson Plan Assessment

In his second lesson plan, Nazım used discussion and predict-observe-explain techniques to teach about carbohydrates. The teacher explained the topic by asking questions to students. All information about carbohydrates and their importance for the human body was explained without technology. After that, the teacher opened a simulation on the smart board replicating the process of color change in different foods with the help of an iodine solution. First, students wrote their prediction about whether a specific food contains carbohydrates or not on their worksheets. Then, volunteer students performed the activity using the simulation on the board. This plan was scored at the *Accepting (2)* level for *C1-Overarching Conception* and *C4-Instructional Strategies* components of the TPACK levels rubric because the technology was mostly used for teacher demonstration, no inquiry tasks were provided to students, and the instructions were teacher-directed (Figure 4.15). For *C2-Student Understanding* and *C3-Curriculum* components, this plan was scored as transitioning from *Accepting* to *Adapting (2.5).* Technology was not used for independent student explorations, and only volunteer students repeated the steps demonstrated by their teacher. Even though selected technologies were aligned with curriculum goals, technology was being used as an add-on to standard approaches of teaching. In his interview, he stated that “I used this simulation because iodine solution may be hard to find in schools. This is a simple experiment. Using the simulation or performing the experiment are the best ways to teach this topic”. As he also stated, technology integration did not make any significant contribution to the teaching of this topic.

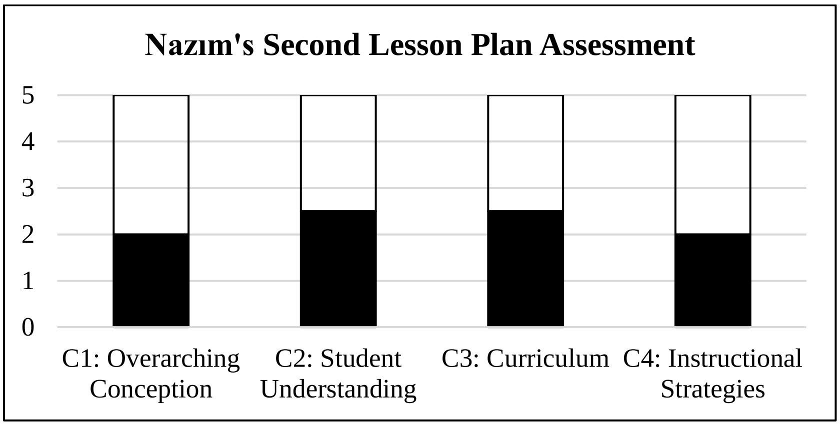

Figure 4.15 Nazım's Second Lesson Plan Assessment

In her second lesson plan, Tomris selected the topic of liquid pressure to be taught by using the POE method. First, students performed and experiment about liquid pressure using a syringe. Then, students used a simulation to investigate the factors affecting liquid pressure on their own. The teacher distributed a worksheet with three screenshots from the simulation. Students were expected to replicate the same conditions and write down what they observed. At the end, the teacher asked questions about students’ observations and summarized the topic. Lastly, students took an online quiz about the topic. In this plan, students used technology to manipulate variables and make observations; however, the given tasks were too prescribed. Students were using technology to learn new information under the control of their teacher. The given questions in the worksheet were a replacement for textbook questions. For these reasons, this plan was scored at the Adapting (3) level for all components of the TPACK levels rubric (Figure 4.16). In the interview, she stated that “I had difficulty while preparing a worksheet for this activity. I could not determine what students should make predictions and observations about". She was able to select compatible technology, content, and pedagogy; however, she had difficulty combining them in an effective manner.

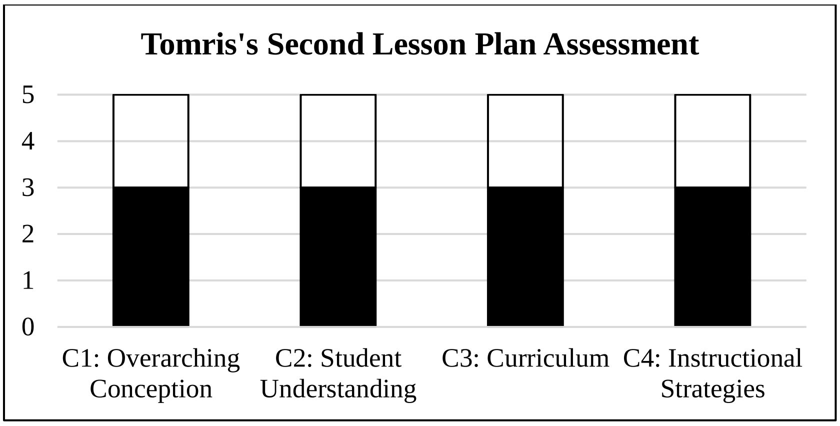

Figure 4.16 Tomris's Second Lesson Plan Assessment

Gülten used a mobile application to teach skeletal system using the demonstration method. After checking students' prior knowledge and making students fill out KWL charts, the teacher showed and explained the structures of the skeletal system using the application. The teacher explained the classification of bones and showed their places. After she finished her demonstration, students were given time to use the application on their own. Then, students discussed what they observed using the application. In this plan, the teacher used technology for demonstration. Students made observations using technology after they learned about the topic mostly for practice purposes. Technology was used as an add-on to teacher-led instruction even though it was aligned with the curriculum. Therefore, this plan was scored as transitioning from *Accepting* to *Adapting* (2.5) for all components of the TPACK levels rubric (Figure 4.17). In the interview, she mentioned that "I had difficulty integrating this technology at first, but when I used KWL chart, it became easier to determine where to use technology". Even though the KWL chart could have been used with a more student-centered approach, she preferred demonstration because it was easier for the teacher.

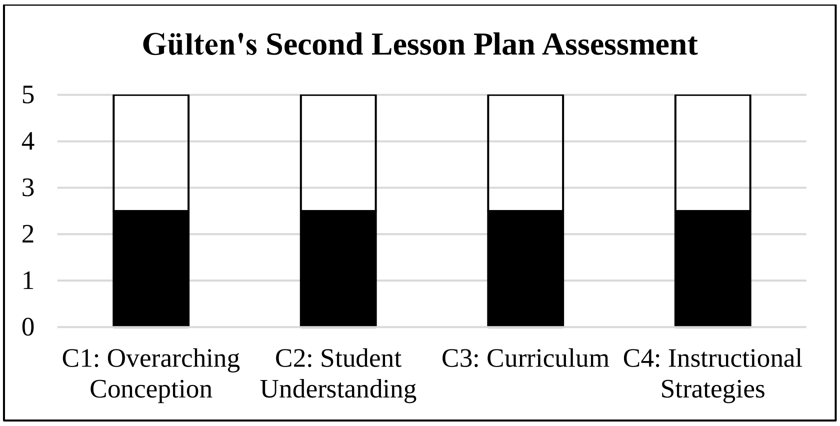

Figure 4.17 Gülten's Second Lesson Plan Assessment

Özdemir used a computer program to show students celestial bodies using the 5E learning cycle method. First, students watched a video about meteors. Then, the teacher distributed activity sheets to students to be filled out while the teacher showed stars and planets using the program. Students observed the differences between stars and planets and recorded their observations. Then, the teacher asked questions about their observations and summarized the topic. Lastly, they watched a video about the sun and observed the sun on the program. Even though the selected technology was appropriate for student explorations, it was mostly used by the teacher for demonstrations. There were no inquiry activities for students. For these reasons, this plan was scored as transitioning from *Accepting* to *Adapting (2.5)* for *C1-Overarching Conception* and *C2-Student Understanding* components (Figure 4.18). Since technology based tasks were not significantly different from traditional curriculum activities and a teacher-directed approach was used to teach with technology, *Adapting (3)* level was achieved for *C3-Curriculum* and *C4-Instructional Strategies* components of the TPACK levels rubric. In the interview, he stated that "for this topic, technology should be used because it is not possible for students to make observations otherwise". He was able to identify a topic from the curriculum for which technology use is effective and appropriate.

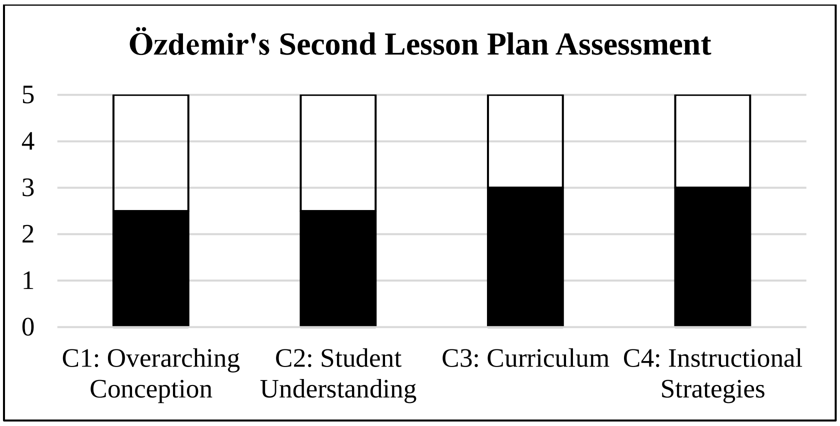

Figure 4.18 Özdemir's Second Lesson Plan Assessment

Cemal taught moon phases using the 5E learning cycle method. First, students performed an activity about moon phases using a ping pong ball hanging from a box with holes to observe and a flashlight. After they made observations about moon phases, the teacher used a simulation for elaboration to show students the rotational movement of the moon. For assessment, students were asked to observe the moon for a month and prepare an online moon calendar. In this plan, technology was mainly used for teacher demonstrations, and there were no inquiry tasks for students with technology. For this reason, this lesson plan was scored at the *Accepting (2)* level for *C1-Overarching Conception* and *C4-Instructional Strategies* components (Figure 4.19). For *C2-Student Understanding* and *C3-Curriculum* components, this plan was scored as transitioning from *Accepting to Adapting (2.5)*. Even though the technology was appropriate for independent student explorations, it was used by the teacher for demonstration. Mostly standard approaches were used for teaching the topic, and technology was used as an add-on. In the interview, he mentioned that "for this plan, I integrated technology more easily because I did not use it during the main body of the lesson. I focused on using it for assessment. Students will take pictures and then prepare an online calendar". As he stated, technology was not a significant tool for the most part of the lesson. Most of the teaching was done without using technology.

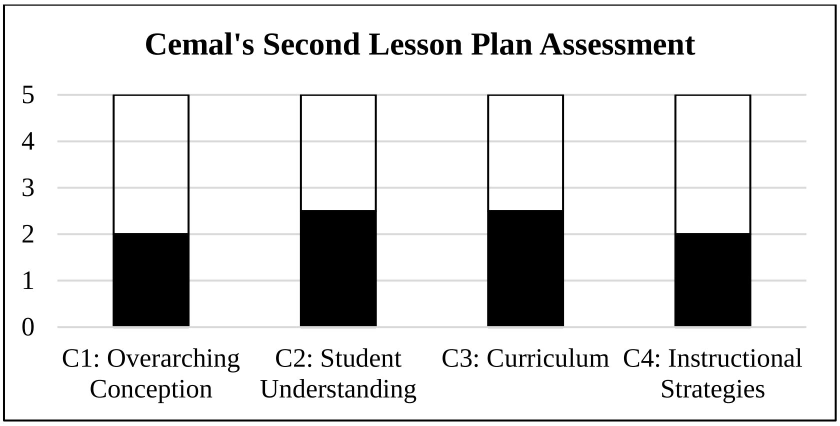

Figure 4.19 Cemal's Second Lesson Plan Assessment

Nilgün used a web-based science lesson to teach students the topic of thermal conductivity. At the beginning of the lesson, the teacher showed a video about thermal conductivity and asked questions about this phenomenon. Then, students were directed to a website presenting an inquiry-based science lesson where they answered questions, made predictions, collected data, and drew conclusions. In addition, students were asked to take measurements in their classroom and enter data into the website. Since in this lesson, students were engaged in a guided inquiry activity with the help of technology, students were the primary user of technology to do science and learn new information, and the teacher changed the traditional way of teaching this topic, this lesson plan was scored at the *Exploring (4)* level for all components of the TPACK levels rubric (Figure 4.20). In the interview, she mentioned that "The website I used was perfect for inquiry-based learning. It does not only help students to simulate experiments but also includes questions and directions. Students make predictions, collect data, write reflections, and communicate with each other. In addition, it helps the teacher to monitor students' work and assess their performance". She selected a very well-designed and comprehensive online teaching and learning tool for inquiry-based learning. Using this tool, the teacher acted as a guide while students were constructing their own knowledge with the help of technology.

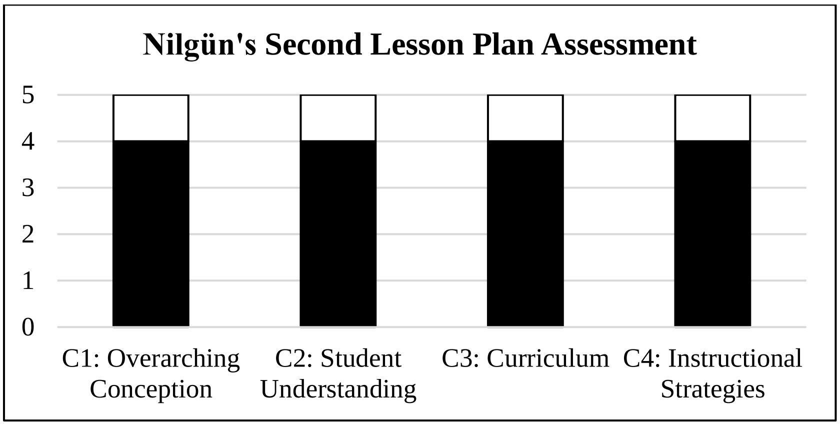

Figure 4.20 Nilgün's Second Lesson Plan Assessment

Most of the second lesson plans submitted by the first cycle participants were scored at the *Accepting* and *Adapting* levels across components. Only one participant was scored at the *Recognizing* level for all components. None of the lesson plans were scored at the *Advancing* level (the highest level of the rubric) for any of the components. *Exploring* was the highest level of scoring across the second lesson plans; which was achieved only by one participant. Table 4.19 presents the assessment of the second lesson plans across the components of the TPACK levels rubric for all participants of the first cycle.

Table 4.19

Assessment of the Second Lesson Plans (Cycle-1)

Participant	C1: Overarching Conception	C2: Student Understanding	C3: Curriculum	C4: Instructional Strategies
Lale	1.0	1.0	1.0	1.0
Nazım	2.0	2.5	2.5	2.0
Tomris	3.0	3.0	3.0	3.0
Gülten	2.5	2.5	2.5	2.5
Özdemir	2.5	2.5	3.0	3.0
Cemal	2.0	2.5	2.5	2.0
Nilgün	4.0	4.0	4.0	4.0

4.3.2.2. Assessment of Second Lesson Plans (Cycle-2)

In this section, findings related to the second lesson plans of second cycle participants are explained. The main components of the second lesson plans are presented in Table 4.20.

Table 4.20

Main Components of Cycle-2 Participants' Second Lesson Plans

Participant	Content	Pedagogy	Technology
Umay	Electric circuits	Analogy	Simulation
Birhan	Electric circuits	Learning cycle	Simulation, online sharing platform
Turgut	Work and energy	5E – Learning cycle	Simulation
Didem	Solar system and planets	Collaborative learning	Interactive website, online sharing platform, video
Ayten	Celestial bodies	5E – Learning cycle	Simulation, online collaboration tool

Using water circuits as the analog concept, Umay taught electrics in her second lesson plan. First, the teacher explained the concept using analogy and defining important concepts. At the end of the lesson, for closure and assessment, students were divided into groups and used a simulation to construct open and closed circuits and make observations related to current, voltage, and flow of electrons. In this plan, technology was used by students to practice the newly learned concepts, and no inquiry activities were prepared for students. Even though technology based tasks were aligned with curriculum objectives, they had a superficial role in the lesson. For these reasons, this plan was scored as transitioning from *Accepting to Adapting (2.5)* for *C1-Overarching Conception* and *C3-Curriculum* components (Figure 4.21). For *C2-Student Understanding* and *C4-Instructional Strategies* components, this plan was scored at the *Adapting (3)* level because students used technology on their own for review of knowledge under the guidance and control of their teacher. In the interview, she stated that "I was planning to use the simulation for the main part of the lesson for teaching the concepts but I also wanted to use analogies. For this reason, I used it for closure and assessment". As she confirmed, this simulation would have been integrated into this lesson in a more student-centered way with an inquiry-based activity; however, she preferred to use analogies.

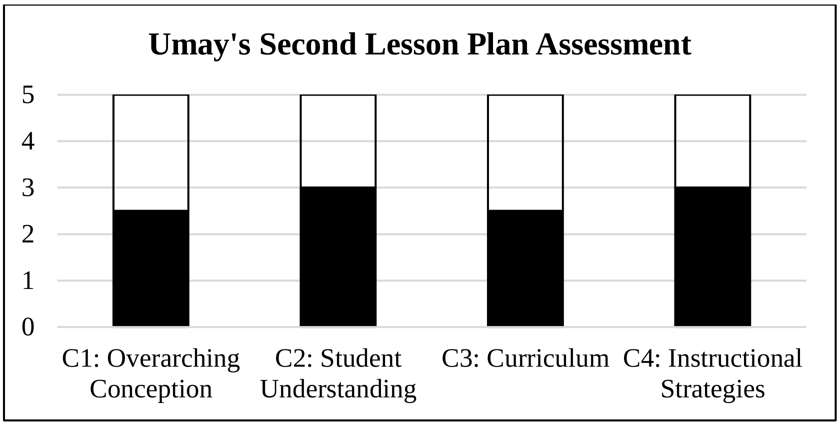

Figure 4.21 Umay's Second Lesson Plan Assessment

Birhan also selected electric circuits as the topic to be taught using a simulation. She used the learning cycle as the teaching method. First, the teacher checked students' prior knowledge and reminded previous information about how electric circuits work. Then, she explained the symbols of electric circuit elements. After that, students formed groups and created a model of electric circuit using symbols. Then, they constructed these circuits on a simulation and shared their models with their peers and teacher on a sharing platform. This plan was scored as transitioning from *Accepting to Adapting (2.5)* for *C1-Overarching Conception* and *C3-Curriculum* components because the technology was used by students to practice the newly learned concepts, and no inquiry activities were prepared for students (Figure 4.22). The teacher explained the topic beforehand and used technology as an add-on. For *C2-Student Understanding* and *C4-Instructional Strategies* components, this plan was scored at the *Adapting (3)* level because mostly a teacher directed approach was used to teach new information even though students were given a chance to practice with technology. She mentioned in the interview "this simulation helps students see symbols and pictures of electric circuit elements at the same time. Also, students can construct their own circuits to see whether it works or not". She used technology for practice purposes to support students' learning.

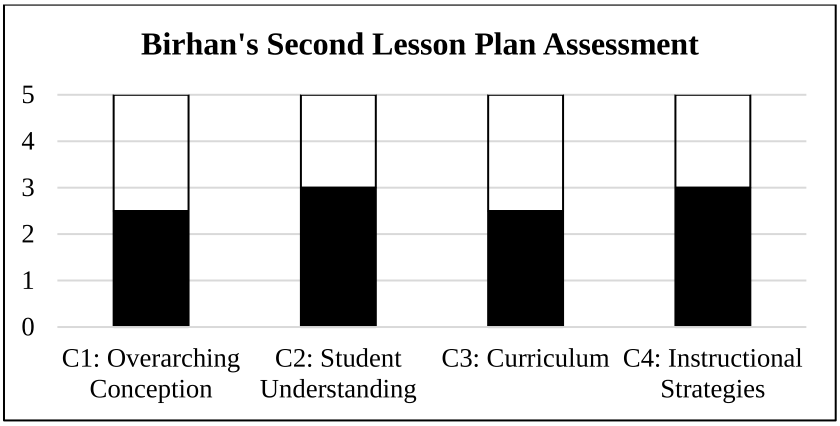

Figure 4.22 Birhan's Second Lesson Plan Assessment

Turgut used a simulation to teach students potential and kinetic energy using the 5E learning cycle method. In this lesson, students were given worksheets with data tables to be filled. They were instructed to change the values in the simulation (e.g., the height of an object from the ground, the speed of a car) and record the potential/kinetic energy. After students collected data using a simulation, they were asked to draw conclusions. For elaboration, the teacher showed an animation related to the relationship between kinetic and potential energy and asked students to explain how they are related. In this lesson, technology was mostly used by students to learn new information and develop connections. The teacher acted as a guide while students made observations related to kinetic and potential energy. However, the activity was too prescribed; students were told exactly which data to collect and how to collect it. For these reasons, this plan was scored at the *Adapting (3)* level for *C1-Overarching Conception* component and *C2-Student Understanding* components (Figure 4.23). For *C3-Curriculum* and *C4-Instructional Strategies* components, this plan was scored as transitioning from *Adapting* to *Exploring (3.5)* level because the teacher changed the way this topic was traditionally taught and used a combination of deductive and inductive strategies. In the interview, Turgut stated that "simulations are the best technological tools to teach this topic because energy is an abstract concept and simulations help students observe the relationships". He was able to identify an appropriate technology to support his teaching process and make it more effective.

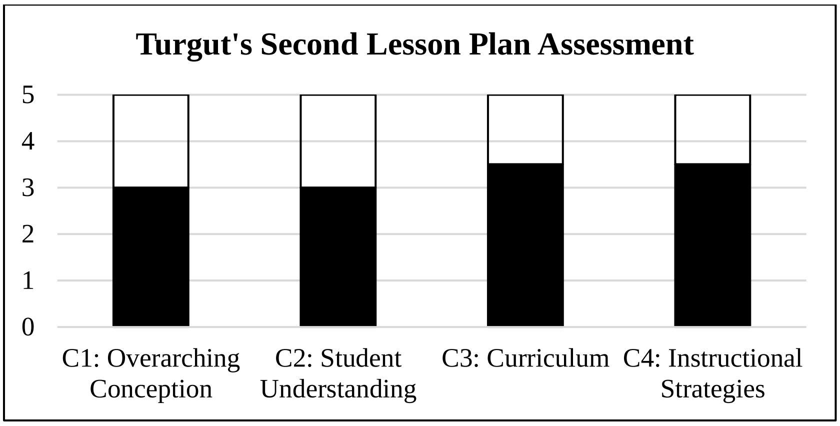

Figure 4.23 Turgut's Second Lesson Plan Assessment

Didem planned a collaborative learning activity to teach students about the characteristic of the solar system. After getting students' attention using a video, the teacher divided the class into small groups and directed students to an interactive website about planets. Each group was assigned a planet and asked to design an aircraft for that planet. Students were told to investigate the characteristics of their planets on the website and create their models accordingly. Each group filled out a worksheet about the characteristics of their planets, the influence of these characteristics on their design, and the final design of their aircrafts. Then, they shared their work with each other using an online sharing platform. After all groups shared their work, students were instructed to read and learn about their peers' work. In this plan, technology was used by students to learn new information, communicate with each other, and share their work. Students explored and compared the planets on their own to complete given tasks. Even though a student-centered approach was used to teach the topic, the selected technologies did not allow students to take actions on objects or ask their own questions to investigate. For these reasons, this plan was scored as transitioning from *Adapting* to *Exploring (3.5)* level for all components of the TPACK levels rubric. In the interview, she stated that "I created a student-centered lesson and organized the technology to support this design". Even though she selected a student-centered pedagogy, the selected technologies were not flexible enough to support it. Technology did not allow students to develop their own strategies for investigating the topic.

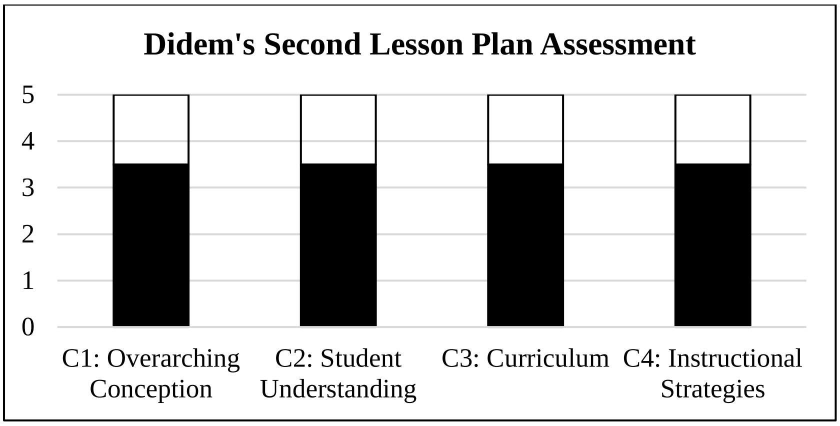

Figure 4.24 Didem's Second Lesson Plan Assessment

Ayten used the 5E learning cycle to teach students about stars and planets using a simulation. First, the teacher gave definitions of stars and planets and explained the topic briefly to the students. Then, students formed groups and, using a simulation, selected a random star in the solar system and explored its characteristics. While doing this, they recorded their findings on an online collaboration platform for their teacher and peers to see. Then, using the simulation, they created an imaginary planet within this star's habitual zone and compared it with Earth. After each group finished their exploration, they summarized their findings, and a classroom discussion was held about stars and planets. This lesson plan was scored at the *Accepting (2)* level of the TPACK levels rubric for *C3-Curriculum* component. For the other components, it was scored as transitioning from *Accepting* to *Adapting (2.5)* because the main concepts of the topic were taught beforehand by the teacher without technology (Figure 4.25). The students used simulation to make observations about stars; however, most of the data provided by the simulation was beyond the scope of the curriculum. Even though students were the primary user of technology for active explorations, the contribution of technology to teaching the topic was limited. In the interview, she mentioned that "the simulation did not present much information about the content. First, I explained the topic, then, I used technology for student practice". The selected technology was not appropriate for teaching this topic and did not support students' understanding of the main concepts of this topic.

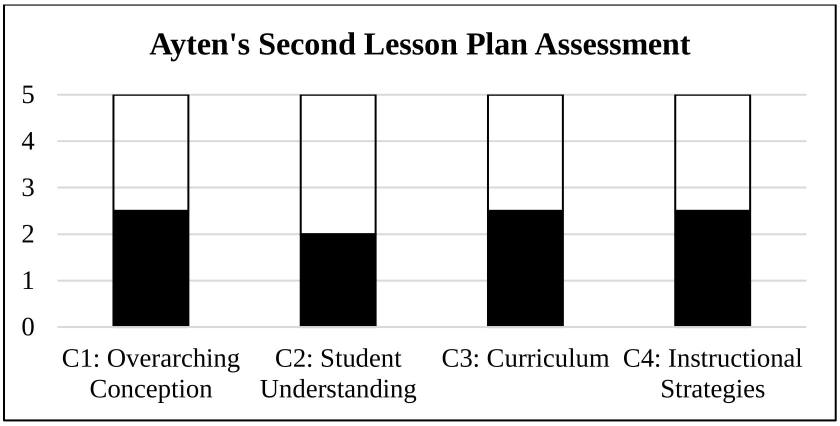

Figure 4.25 Ayten's Second Lesson Plan Assessment

Most of the second lesson plans submitted by the second cycle participants were scored at the *Accepting* and *Adapting* levels across components. None of the lesson plans were scored at the *Exploring* and *Advancing* level (the top two levels of the rubric) for any of the components. There were two participants who were scored as transitioning from *Adapting* to *Exploring* for some components. Table 4.21 presents the assessment of the second lesson plans across the components of the TPACK levels rubric for all participants of the second cycle.

Table 4.21

Assessment of the Second Lesson Plans (Cycle-2)

Participant	C1: Overarching Conception	C2: Student Understanding	C3: Curriculum	C4: Instructional Strategies
Umay	2.5	3.0	2.5	3.0
Birhan	2.5	3.0	2.5	3.0
Turgut	3.0	3.0	3.5	3.5
Didem	3.5	3.5	3.5	3.5
Ayten	2.5	2.0	2.5	2.5

4.3.2.3. Summary of the Findings for Second Lesson Plans

The lowest score received across the components of the rubric determines the overall TPACK level. The distribution of participants from both cycles across different levels for the components of the TPACK levels rubric and overall TPACK level was shown in Figure 4.26.

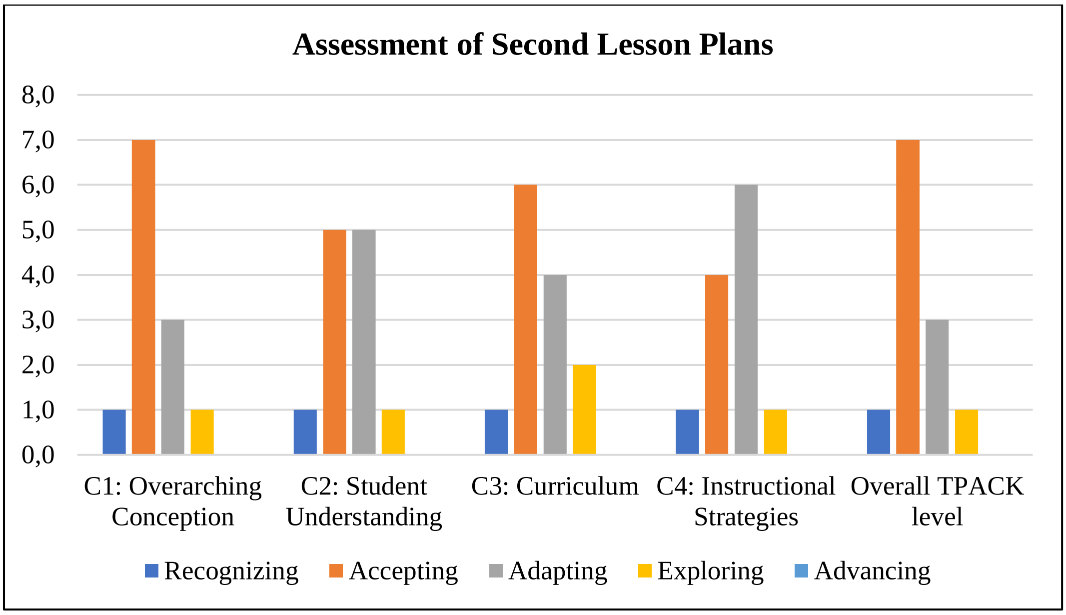

Figure 4.26 Assessment of Participants' Second Lesson Plans

Assessment of second lesson plans revealed that at the end of the *Theory* stage, most of the participants were at the *Accepting* level in terms of overall TPACK. Four of them were also at this level at the beginning of the course (Gülten, Özdemir, Umay, and Birhan). In their second lesson plans, they used technology mostly for teacher demonstrations or low-level practice tasks instead of active student explorations. Two of the participants (Cemal and Ayten) regressed to this level; their first lesson plans received better scores. In their first lesson plans, both of them used technology to teach the main concepts and used technology in a student-centered way. However, in their second plans, technology did not make a significant contribution to the teaching of the main concepts. One participant, Nazım, increased his level of TPACK from *Recognizing* to *Accepting*. In his first lesson plan, technology was just used for practical purposes, whereas in his second plan, he selected a technology to simulate a traditional experiment. He used technology for teaching the concept in his second plan; however, the selected technology did not improve the teaching process when compared to traditional methods.

One of the participants, Lale, stayed at the *Recognizing* level in terms of overall TPACK. Similar to her first lesson plan, she used technology just for practical purposes without any improvements to her teaching process.

At the end of the *Theory* stage, three participants' overall TPACK was at the *Adapting* level. Didem's overall TPACK level did not change, and she was scored at the *Adapting* level for both of her lesson plans. Tomris's level of TPACK increased from *Recognizing* to *Adapting*. In her first plan, she just used a video to summarize the topic; however, in her second lesson plan student used a simulation to learn new information. Turgut progressed from *Accepting* to *Adapting* in his second lesson plan. He used a simulation to make students learn or practice new information about the topic. Even though students were the primary user of the technology to learn new information, their explorations were limited by their teacher with the help of worksheets that specifically told students what to do.

Nilgün's overall TPACK level was at the *Exploring* level for both of her lesson plans. Her lesson plans included inquiry activities where students construct their own knowledge with the help of technological tools while the teacher acted as a guide during students' independent explorations.

4.3.3. Participants' TPACK Level at the End of the Application Stage

Participants submitted their third lesson plans at the end of the *Application* stage of the course after they attended four course meetings about different technological tools that can be used in science education. During this stage, it was aimed to familiarize science teachers with various technological tools and encourage them to discuss which content and pedagogy can be combined with those technological tools. There were no limitations regarding content, pedagogy, and technology.

Using their third lesson plans, participants performed a 40 min micro-teaching during the *Practice* stage. The purpose of these micro-teachings was to give participants a chance to implement a technology integrated science lesson plan and put their newly gained technological knowledge into action. The video-recordings of participants' micro-teachings were also used for the assessment of their lesson plans.

*4.3.3.1. Assessment of Third Lesson Plans (*Cycle-1*)*

This section presents findings related to the third lesson plans of first cycle participants. The main components of their lesson plans are presented in Table 4.22.

Table 4.22

Main Components of Cycle-1 Participants' Third Lesson Plans

Participant	Content	Pedagogy	Technology
Lale	Food chain	Inquiry-based learning	PowerPoint, simulation
Nazım	Balanced diet	5E – Learning cycle	Web sources, simulation, concept map tool
Tomris	Light & Reflection	Learning cycle	Powerpoint, video, simulation, online quiz, online poster tool
Gülten	Cell and its organelles	5E – Learning cycle	Interactive lesson platform, simulation, online game
Özdemir	Electric circuits	Questioning, direct instruction	Interactive lesson platform, simulation
Cemal	Microscopes	Laboratory work	Interactive lesson platform, virtual laboratory
Nilgün	Evolution and adaptation	Argumentation	Online inquiry space

In her third lesson plan, Lale selected food chains as the topic to be taught by inquiry-based learning. First, she used a presentation to check prior knowledge and introduce the new topic. Then, she distributed worksheets with two questions to be investigated using a simulation. After students completed their exploration and filled out their worksheets, the teacher asked for their observations. Then, the teacher used the simulation to demonstrate how introducing a predator to the ecosystem affects other organisms. Lastly, students formed a hypothesis and tested it using simulation. In this plan, most of the time, students were the primary user of technology to experiment with it; however, the teacher told and demonstrated what to do at each step while students were using the simulation. Even though the selected simulation supported student reflection, a teacher directed approach was used while students were using technology. For this reason, this plan was scored as transitioning from *Adapting to Exploring (3.5)* level for *C1-Overarching Conception, C2-Student Understanding,* and *C4-Instructional Strategies* components. For *C4-Curriculum* component, this plan was scored at the *Exploring (4)* level because the teacher found an alternative way to teach the topic, and the selected technology was aligned with curriculum goals (Figure 4.27). During the micro-teaching, she implemented the lesson exactly as she planned. In the interview, she stated that she implemented this lesson plan in her actual classroom. She mentioned that "I generally use direct instruction and discussion while teaching. For this plan, I took students to the computer laboratory, and students were very excited". She prepared a teacher-directed lesson because she and her students did not have enough experience in using technology while teaching and learning.

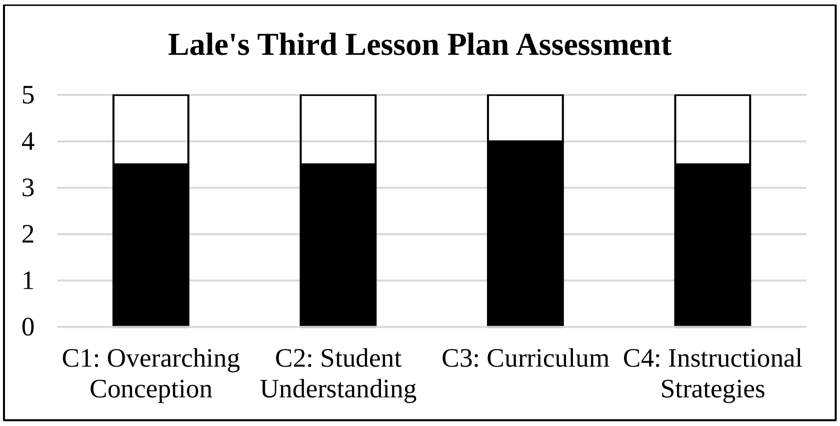

Figure 4.27 Lale's Third Lesson Plan Assessment

Nazım used various technologies to teach the topic of balanced diet using the 5E learning cycle teaching method. First, he used an online graphic showing the diet patterns of people in different countries. Then, he opened the simulation and asked students which foods should be included in a healthy diet. A volunteer student created this diet in the simulation based on his classmates' ideas, and they observed its influences on the human body. After that, the teacher asked questions about their observations. Lastly, he summarized the topic and used an online concept mapping tool to construct a concept map as a class. In this plan, the teacher was the one actively using technology while teaching a new topic. Even though the integration of technology enhanced the teaching and learning process, students did not get a chance to use technology for active explorations. The teacher controlled the use of technology and tried to engage students with questions. For these reasons, this plan was scored at the *Adapting (3)* level for all components of the TPACK levels rubric (Figure 4.28). He implemented his plan without any alterations in his micro-teaching. In the interview, he stated that "I made my lesson more teacher-centered while using technology and tried to engage students with questioning to prevent problems that might occur if students were using technology on their own". He did not feel comfortable enough to give up control while teaching with technology.

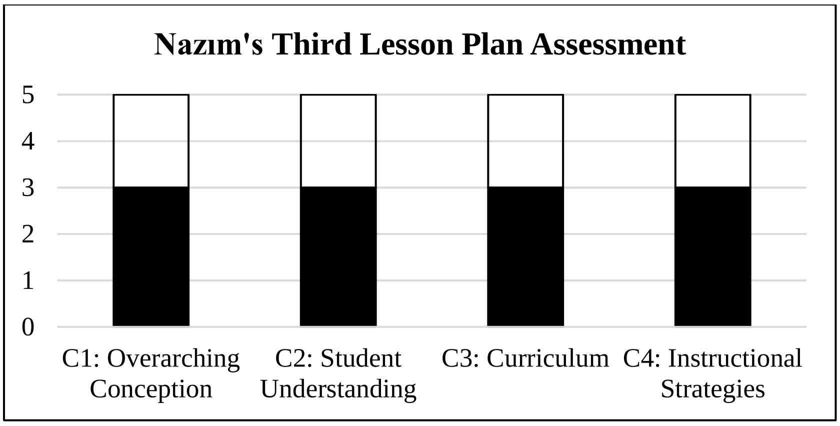

Figure 4.28 Nazım's Third Lesson Plan Assessment

Tomris selected the topic of light reflection to be taught using a simulation. First, she made a presentation about previously learned concepts. Then, she asked questions about light reflection and introduced the activity with the help of a short video about mirrors and light reflection. Students used a simulation to change the direction of light with the help of mirrors and tried to illuminate specified areas. They observed how light is reflected using the simulation. At the end of the lesson, students discussed their observations and the teacher asked questions about daily life examples. She also made an online quiz and asked students to design a periscope and prepare an online poster as homework. In this plan, a teacher guided inquiry activity was implemented with the help of technology; students used technology to do science, make observations and inferences, and learn new information. The teacher changed the traditional way of teaching this topic, and she planned a student-centered lesson where students construct their own knowledge with the help of technology. For these reasons, this plan was scored at the *Exploring (4)* level for all components of the TPACK levels rubric (Figure 4.29). She performed her micro-teaching as she planned without any changes. In the interview, she stated that "I think this time I integrated technology better when compared to my other lesson plans. Technology had more contribution to my plan this time". After learning about different technologies during the *Application* stage, it became easier for her to prepare a technology integrated lesson plan.

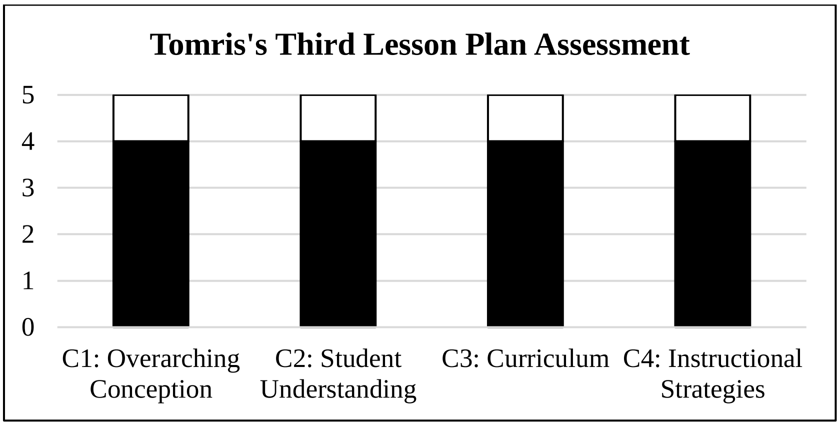

Figure 4.29 Tomris's Third Lesson Plan Assessment

To teach about cell and its organelles, Gülten used the 5E teaching method enriched by different technologies. She used an interactive lesson platform to keep her students engaged. After a brief introduction, students used a simulation to observe plant and animal cells, organelles, and structures. The teacher distributed an activity sheet including the question about organelles, their structure, and functions. Then, they made observations about the differences between plant and animal cells. After students' exploration, the teacher opened an online game, and students placed organelles in a cell figure. Lastly, using the interactive lesson platform, students completed a quiz about the topic. Since the technology was mostly used by students for exploration of the topic, this plan was scored as transitioning from *Adapting* to *Exploring (3.5) for C1-Overarching Conception* component. For the other components, this lesson plan was scored at the *Adapting (3)* level since the technology was used as a replacement for non-technology based tasks, selected technologies did not allow students to take actions on objects, and the teacher controlled the progression of the activities via activity sheets (Figure 4.30). She did not make any changes during her micro-teaching. In the interview, she stated that "the textbook images for the cell are not in good quality; technology provides a better visualization for students". Even though she tried to make her lesson more student-centered, technology based activities were mostly a replacement for traditional tasks.

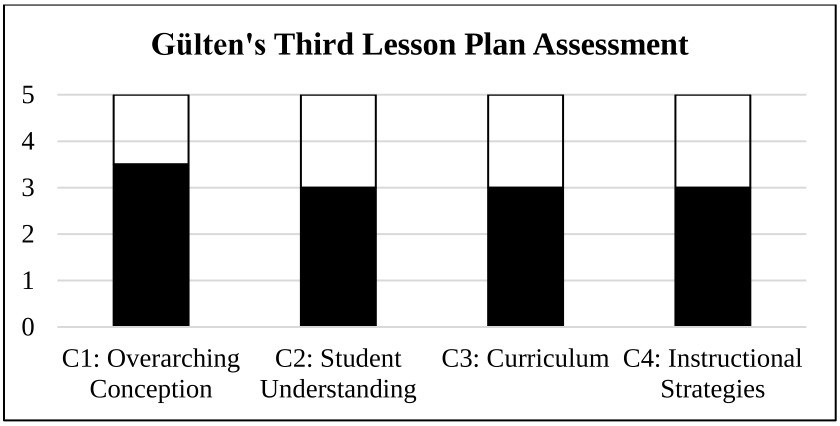

Figure 4.30 Gülten's Third Lesson Plan Assessment

Özdemir used an interactive lesson platform to monitor students' work while teaching about electric circuits and symbols. First, the teacher gave brief information about the topic. Then, students were given instructions to construct different electric circuits using a simulation. The teacher gave directions about the components to be used. Using the simulation, the students observed the symbolic representations of their electric circuits. Then the teacher asked students to draw symbols using the online platform to see their answers immediately. Lastly, the teacher summarized the topic. Students were using technology to learn and practice new information, take actions on scientific objects and observe the results; however, the activities were too prescribed. For this reason, this plan was scored as transitioning from *Adapting* to *Exploring (3.5) C1-Overarching Conception* and *C2-Student Understanding* components (Figure 4.31). Even though the selected technologies were aligned with curriculum goals, a teacher directed approach was used to teach with technology. Therefore, this plan was scored at the *Adapting (3)* level for *C3-Curriculum* and *C4-Instructional Strategies* components (Figure 4.31). He implemented his lesson plan without any changes during his micro-teaching. In the interview, he mentioned that "I tried to make students active and engaged. That's why I used the online lesson platform and asked too many questions". His intention was to prepare a student-centered lesson; however, the activities he prepared were too prescribed. He did not give students a chance to make their own explorations with technology. The questions and activities did not promote high level thinking.

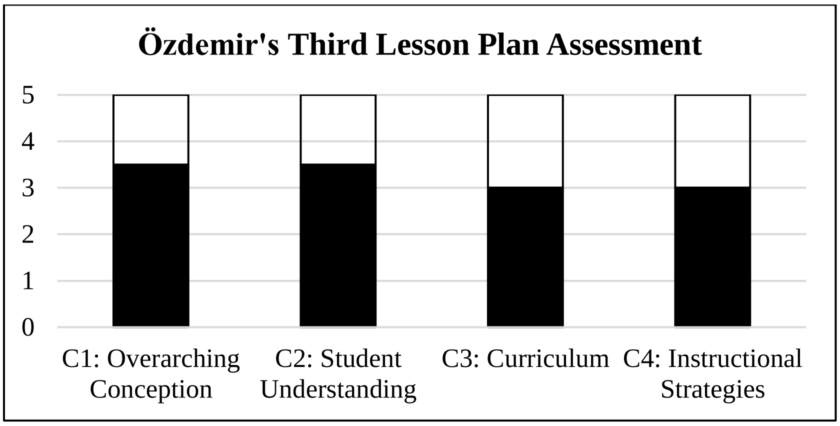

Figure 4.31 Özdemir's Third Lesson Plan Assessment

Cemal used a virtual laboratory application to teach how to use a microscope. In order to monitor students' work using this application, the teacher used an online lesson platform. The teacher directed students to the virtual laboratory, where they learned how to use a microscope under the guidance of a virtual assistant. Students experienced the steps of obtaining a fine image using a microscope with the directions and feedback provided. The virtual assistant told and showed students what to do at each step. Then, the teacher asked labeling questions using the online platform. In this plan, students used the virtual lab to simulate using a microscope; however, students' explorations were limited by the selected technology. The virtual assistant gave instructions at each step, and students were just following the instructions and reading the explanations provided. Since the teacher controlled and limited what students did with technology, this plan was scored at the *Adapting (3)* level for all components (Figure 4.32). He implemented his lesson plan without any changes. In the interview, he stated that "the virtual assistant of the technology acts like a teacher and teaches students how to use microscopes. The teacher does not have much role while students are using this technology". As he stated, the technology he selected was too structured and guided. Students could have used this technology on their own outside the classroom without their teacher.

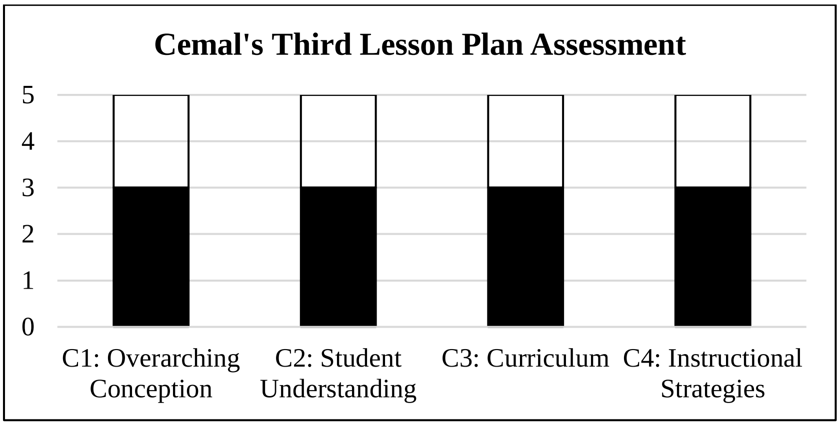

Figure 4.32 Cemal's Third Lesson Plan Assessment

Nilgün used an online inquiry space to teach evolution and adaptation to students. Using this online platform, she prepared a lesson for her students to guide them through their explorations. Students formed groups and were given five different scenarios related to natural selection to be investigated using a simulation. After students finished their explorations, they were provided with two possible explanations for their observations. Students chose one of the explanations and were asked to support it with their observations. After they entered their ideas into the online space, each group presented their ideas, and a classroom discussion was held, and the teacher directed students toward the correct explanation with questions. This lesson plan was scored at the *Exploring (4)* level for *C1-Overarching Conception* and *C3-Curriculum* components because the technology was used by students for high-level inquiry activities aligned with curriculum goals (Figure 4.33). The teacher altered the way this topic is generally taught. *For C2-Student Understanding* and *C4-Instructional Strategies* components, this plan was scored as transitioning from *Exploring* to *Advancing* (4.5) because the teacher prepared technology-based tasks to promote high-level thinking and used multiple instructional strategies. Technology-based activities required students to ask questions, justify their explanations, and discuss with each other to draw conclusions. During the micro-teaching, she implemented this plan without any alterations. In the interview, she stated that "I try to make my lesson student-centered as much as possible. Otherwise, students do not give their attention". She effectively combined technology, content, and pedagogy to teach a difficult concept with active student explorations.

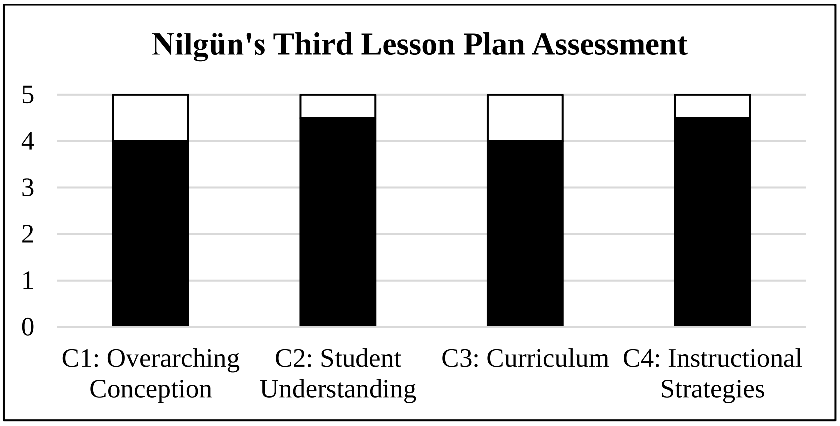

Figure 4.33 Nilgün's Third Lesson Plan Assessment

When participants' scores across components were investigated for third lesson plans, it was seen that participants distributed among *Adapting* and *Exploring* levels. Five participants were scored at the *Adapting* level for all components, and two participants were scored at the *Exploring* level for all components. None of the lesson plans were scored at the *Recognizing*, *Accepting*, and *Advancing* levels for any of the components.

Only one participant's plan was scored as transitioning from *Exploring* to *Advancing* for two components. Table 4.23 presents the assessment of the third lesson plans across the components of the TPACK levels rubric for all participants of the first cycle.

Table 4.23

Assessment of the Third Lesson Plans (Cycle-1)

Participant	C1: Overarching Conception	C2: Student Understanding	C3: Curriculum	C4: Instructional Strategies
Lale	3.5	3.5	4.0	3.5
Nazım	3.0	3.0	3.0	3.0
Tomris	4.0	4.0	4.0	4.0
Gülten	3.5	3.0	3.0	3.0
Özdemir	3.5	3.5	3.0	3.0
Cemal	3.0	3.0	3.0	3.0
Nilgün	4.0	4.5	4.0	4.5

4.3.2.2. Assessment of Third Lesson Plans (2nd Cycle)

This section presents findings related to the third lesson plans of second cycle participants. The main components of their lesson plans are presented in Table 4.24.

Table 4.24

Main Components of Cycle-2 Participants' Third Lesson Plans

Participant	Content	Pedagogy	Technology
Umay	Heat and temperature	Questioning, direct instruction	Interactive lesson platform, simulation
Birhan	Density	Laboratory work	Simulation, video, online sharing platform,
Turgut	Heredity	POE	Simulation, online quiz tool
Didem	Digestive system	5E – Learning cycle	Presentation tool, simulation, augmented reality application, online poster tool
Ayten	Pure substances	5E – Learning cycle	Augmented reality application, classroom management tool, video

Umay used direct instruction and questioning to teach about heat and temperature. After checking prior knowledge, the teacher used an interactive lesson platform to share her presentation about definitions of important concepts with her students on their screens. Then, the teacher directed students to a simulation and gave them instructions about what to do in the simulation. Students changed the variables as instructed and observed what happened. After students finished their exploration, the teacher asked them their conclusions and explanations. The teacher made students reach meaningful conclusions by questioning. Lastly, they summarized the topic, and the teacher gave a mini quiz to the students. In this lesson, students used technology to manipulate variables and make observations, but the activity was too prescribed. Students were told exactly what to do. For these reasons, this plan was scored at the *Adapting (3)* level for *C1-Overarching Conception* and *C2-Student Understanding* components (Figure 4.34). For *C3-Curriculum* and *C4-Instructional Strategies* components, this plan was scored as transitioning from *Adapting* to *Exploring (3.5)* level because the selected technology was aligned with curriculum goals even though a teacher-directed approach was used while students were using it. She implemented this plan exactly in her micro-teaching. In the interview, she stated that "I wanted to use the interactive lesson platform, and I thought the most appropriate method to use it was direct instruction. I tried to keep students engaged with the help of technologies and questioning". As she stated, the technologies she selected made students active during the lesson; however, the tasks with technology were mostly teacher-directed.

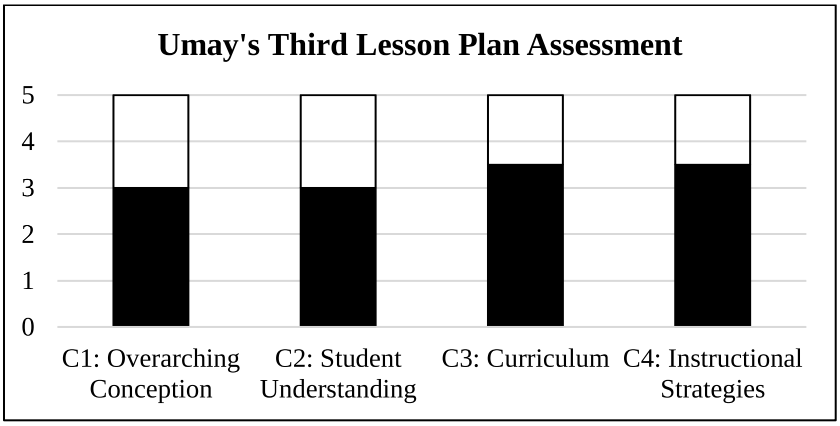

Figure 4.34 Umay's Third Lesson Plan Assessment

Birhan selected laboratory work as the teaching method to teach density using a simulation. First, the teacher made students watch a video about density to get their attention. Then, the teacher directed students to the online sharing platform and instructed them to write their predictions about whether the given objects will float or sink in the water. Then, students were given worksheets with guiding questions. The students used the simulation to measure the mass and volume of objects, calculate their densities and observe whether they float or sink. At the end, the teacher wanted students to explain what makes an object float or sink and summarize the topic. In this plan, students were guided to form the hypothesis, collect data to test it, and draw conclusions. Students manipulated the variables and observed their consequences. Technology-based tasks were aligned with curriculum goals and made students pose questions about the phenomena. For these reasons, this plan was scored at the *Exploring (4)* level for all components of the TPACK levels rubric (Figure 4.35). She did not change anything in her plan for her micro-teaching. In the interview, she stated that "I think this technology (simulations) make it easier for teacher and students to do laboratory work, that's why I selected it. Students construct their own knowledge while experimenting with technology". She prepared a student-centered lesson plan but also monitored and guided them with the help of the technology she selected.

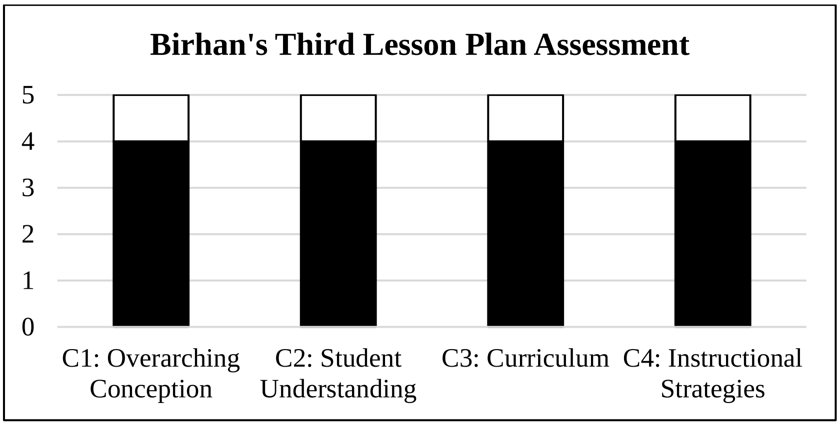

Figure 4.35 Birhan's Third Lesson Plan Assessment

Turgut taught the topic of heredity using the POE technique and a simulation. He also used an online quiz tool to prepare online worksheets for students. The instructions and questions of a worksheet were given online. Students made predictions and observations about breeding mice with different phenotypes and genotypes, collected data, and drew conclusions with the help of guiding questions provided by their teacher. The students explored the topic using a simulation, and the teacher monitored their progress with the help of the online quiz tool. After students completed their exploration of a question, the teacher started a classroom discussion and guided students to reach meaningful explanations. In this plan, students used technology to simulate an experiment, ask questions, make observations, and draw conclusions. Instead of telling students what to do, the teacher directed open-ended questions for students to investigate. Using both inductive and deductive strategies, the teacher helped students draw meaningful conclusions. Selected technologies were aligned with the curriculum goals and useful to teach this topic in a different way. For these reasons, this plan was scored at the *Exploring (4)* level for all components of the TPACK levels rubric (Figure 4.36). He performed his micro-teaching based on this plan without any changes. In the interview, he mentioned that “I used a quiz tool to prepare an online worksheet to be able to see students’ responses simultaneously. By this way, when discussing their observations, I guided them better”. He adapted a technological tool according to his needs to improve the process of teaching and learning.

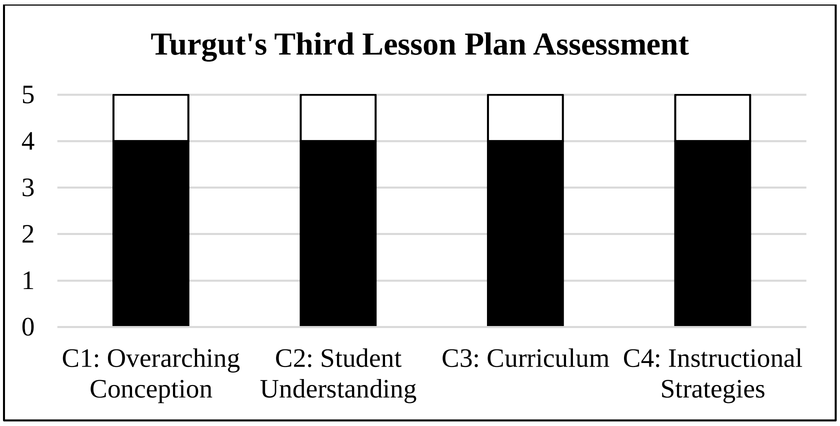

Figure 4.36 Turgut's Third Lesson Plan Assessment

In her third lesson plan, Didem taught the topic of the digestive system using the 5E learning cycle method and integrating various technological tools. First, the teacher used a presentation program to remind previously learned concepts. Then, using an augmented reality application, students observed the systems of the human body. The teacher instructed them to focus on the digestive system. Then, students were given worksheets and directed to a simulation. In this worksheet, students were first asked to match organs with their functions according to explanations provided by the simulation. Then, they were asked to construct their own digestive system using the simulation. After finishing their design, they observed it processing food and recorded what percentage of calories and water were observed by their design. Then, based on their results, they were asked to assess their designs and try to improve them. Then a classroom discussion was held about working and not working designs, the ideal model of the digestive system, and students' observations. Lastly, they were asked to investigate diseases of digestive systems and prepare online posters. In this plan, the teacher improved the traditional approaches of teaching this topic with the help of a technology aligned with curriculum goals. Instead of making students memorize the organs and their functions, the students found the working model of the digestive system by actively constructing models and observing the consequences. For these reasons, this plan was scored at the *Exploring (4)* level for all components of the TPACK levels rubric (Figure 4.37). During micro-teaching, she had trouble managing her time. In the interview, she mentioned that "Students should be given more time with this simulation when implementing this lesson plan in an actual classroom environment". She selected effective technologies to teach this topic; however, she could not use time effectively. She planned so many student-centered activities for a single lesson, and it became difficult to implement all of them.

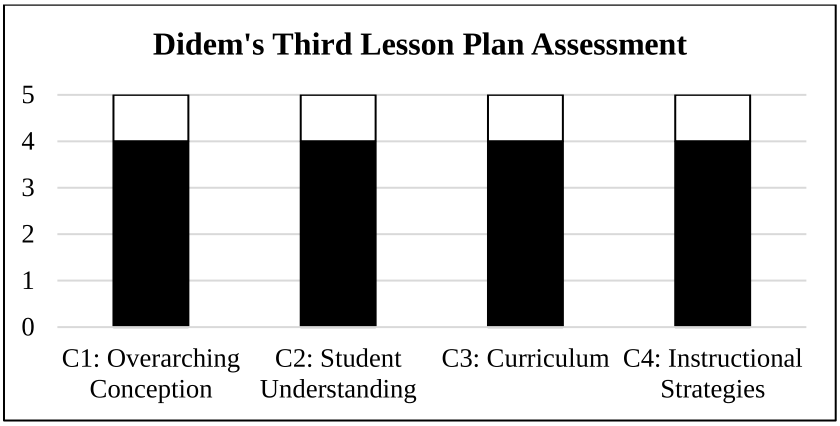

Figure 4.37 Didem's Third Lesson Plan Assessment

To teach students the first 18 elements of the periodic table, Ayten used the 5E learning cycle method and an augmented reality application. The teacher started the lesson by making a presentation about previously learned information about pure substances and the characteristics of elements. Then, students watched a video about elements, their characteristics, and their symbols. Then, using a classroom management tool, two students groups were formed. One group became the teller, and the other group became the guesser. The teller group was given an augmented reality card and an information card about a particular element. The teller group studied the given information and tried to make the other group guess the element. After the guessing part was complete, the guesser group got the augmented reality card and explored the characteristics of that element. Then, groups switched roles, and the game continued for different elements. After the game, the teacher showed the list of elements and symbols and wrapped up the lesson. In this plan, there were no inquiry tasks for students, and technology was mostly used for learning new information. Selected technologies did not promote student reflection, mostly used as an add-on to traditional approaches of teaching. Technology-based tasks were mostly a replacement for traditional non-technology tasks in the curriculum. Even though the application provided students an environment to observe the natural state of elements, it was mostly used for reading information. Therefore, this plan was scored as transitioning from *Accepting* to *Adapting (2.5)* for all components (Figure 4.28). In her micro-teaching, she faced many problems while setting the rules for the game. She did not plan the activity very well.

In her interview, she said that “I did not think about the game rules very much. It would be difficult to implement with actual students in a classroom setting”. As she stated, technology integration and activities with technology were problematic. She could have integrated it better with a well-structured lesson plan.

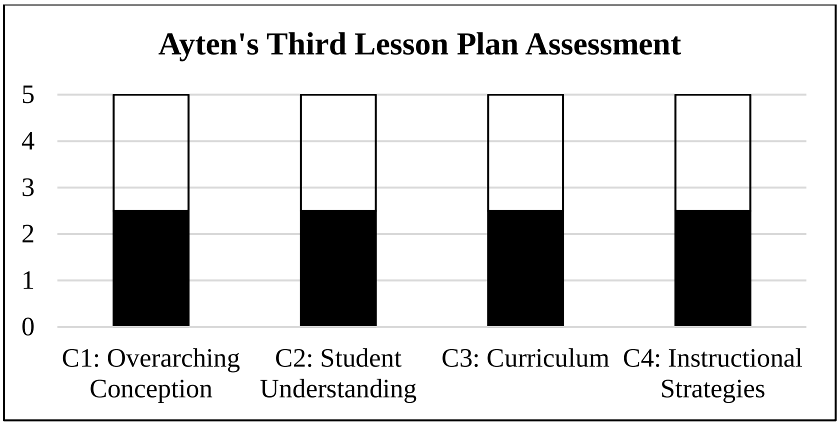

Figure 4.38 Ayten's Third Lesson Plan Assessment

Investigation of participants’ scores across components for third lesson plans revealed that three of the participants were scored at the *Exploring* level for all components. There was one participant scored at the *Adapting* level and one participant at the *Accepting* level. None of the lesson plans were scored at the *Recognizing*, and *Advancing* levels for any of the components. Table 4.25 presents the assessment of the third lesson plans across the components of the TPACK levels rubric for all participants of the first cycle.

Table 4.25

Assessment of the Third Lesson Plans (Cycle-2)

Participant	C1: Overarching Conception	C2: Student Understanding	C3: Curriculum	C4: Instructional Strategies
Umay	3.0	3.0	3.5	3.5
Birhan	4.0	4.0	4.0	4.0
Turgut	4.0	4.0	4.0	4.0
Didem	4.0	4.0	4.0	4.0
Ayten	2.5	2.5	2.5	2.5

4.3.3.3. Summary of the Findings for Third Lesson Plans

Participants' overall TPACK level is determined by the lowest score they receive across the components of the TPACK levels rubric. Figure 4.39 presents the distribution of participants from both cycles across different levels for the components of the TPACK levels rubric and overall TPACK level.

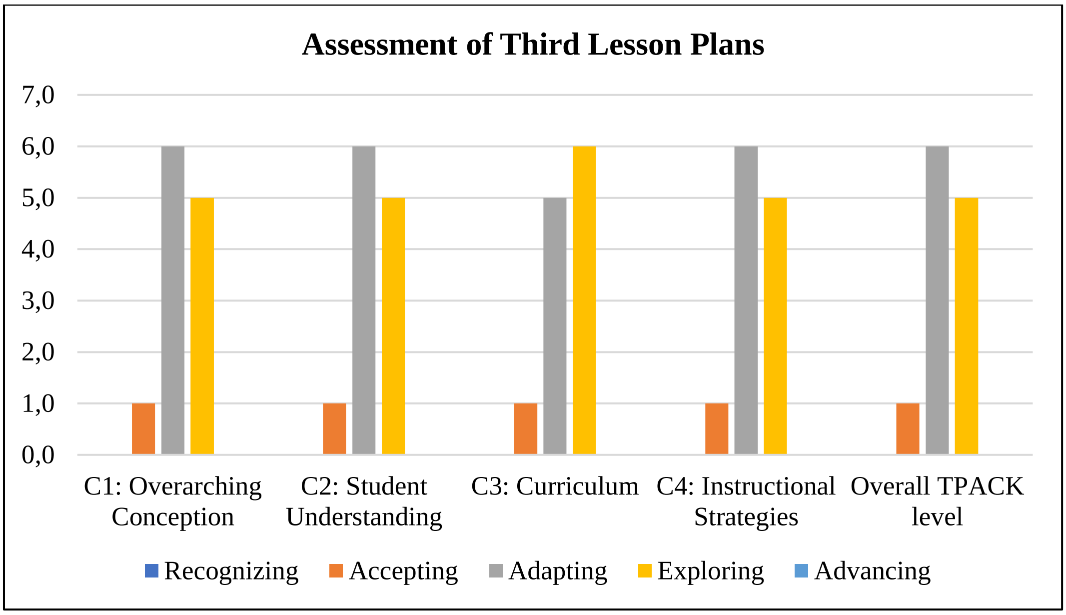

Figure 4.39 Assessment of Participants' Third Lesson Plans

Assessment of third lesson plans revealed that, at the end of the *Application* stage, none of the participants was scored at the *Recognizing* level and *Advancing* level for any of the components. *Advancing* level, the highest possible level of the rubric was not reached by any of the participants in any of the lesson plans.

Lale was the only participant with the overall TPACK level of *Recognizing* at the end of the Theory stage. For her third lesson plan, she received scores of 3.5 and 4 across different components, and her overall TPACK level was determined as *Adapting*. She prepared a lesson plan where students were actively using technology to explore the topic under the guidance of the teacher. She did not give up control when her students were using technological tools.

Five other participants were also at the *Adapting* level. Nazım, Gülten, Özdemir, Cemal, and Umay increased their level of TPACK from *Accepting* to *Adapting* in their third lesson plans. The participants at this level planned technology-based exploration activities for their students; however, they were generally too prescribed; the teacher controlled how students used technology to learn new information.

Ayten's level of TPACK stayed at the *Recognizing* level at the end of the Application stage. The activity she planned did not include any inquiry tasks for students, and technology was used as a medium for learning new information and as an add-on to standard activities of teaching.

Five of the participants' overall TPACK level was determined to be at the *Exploring* level. Nilgün was the one participant who received the same score for all of her lesson plans. Tomris, Turgut, and Didem increased their level of TPACK from *Adapting* to *Exploring*. Birhan increased her level of TPACK to the *Exploring* level from *Accepting*. All of their plans included student-centered activities facilitating students' independent exploration with technology to learn new information on their own. They changed the traditional approaches of teaching and used various strategies to promote student reflection.

4.3.4. Participants' TPACK Level at the End of the Course

Participants submitted their last lesson plans at the end of the *Practice* stage, which also corresponded to the end of the semester. They performed micro-teachings during the *Practice* stage to experience the implementation process of a technology integrated science lesson plan. In addition, they had a chance to observe each other and give and receive feedback from their peers, their instructor, and the researcher.

*4.3.4.1. Assessment of Fourth Lesson Plans (*Cycle-1*)*

In this section, findings related to the fourth and last lesson plans of first cycle participants are explained. The main components of the fourth lesson plans selected by participants are presented in Table 4.26.

Table 4.26

Main Components of Cycle-1 Participants' Fourth Lesson Plans

Participant	Content	Pedagogy	Technology
Lale	Acids and bases	Inquiry-based learning	PowerPoint, virtual lab.
Nazım	Digestive system	Project-based learning	Web page with mini activities
Tomris	Mitosis and meiosis	Role playing, discussion	Internet sources, animation
Gülten	Digestive system	5E – Learning cycle	Simulation, online game, interactive lesson platform
Özdemir	Skeletal system	5E – Learning cycle	Augmented reality application, interactive lesson platform, spreadsheets
Cemal	Pollination	5E – Learning cycle	Simulation
Nilgün	Force and weight	Inquiry-based learning	Online inquiry space, simulation, digital canvas

In her last lesson plan, Lale selected the topic of acids and bases to be taught using inquiry-based learning. First, the teacher reviewed and checked prior knowledge using a presentation. Then, students were given worksheets with instructions and questions and directed to a virtual lab application to experience the process of pH testing. In this application, students measured the pH value of various substances using pH papers. Then they were asked to determine whether the substance was acid, base or neutral using the pH scale. They were also asked to determine the common characteristics of acidic and basic substances. In this plan, students used technology on their own for exploration; however, their process was controlled and limited by their teacher and the selected technology. Even though the selected technology was aligned with the curriculum goals, it was too structured and limited. It was only a replication of a traditional classroom experiment with pH paper. For these reasons, this plan was scored at the *Adapting (3)* level for all components of the TPACK levels rubric (Figure

4.40). In the interview, she stated that “I selected this virtual lab application because it already had a prepared worksheet guiding students through the activity. Moreover, when compared to doing this experiment in the classroom, it includes a various number of materials to be tested”. She selected a useful technology to replicate an experiment; however, technology-based activities only supported a basic understanding of the topic.

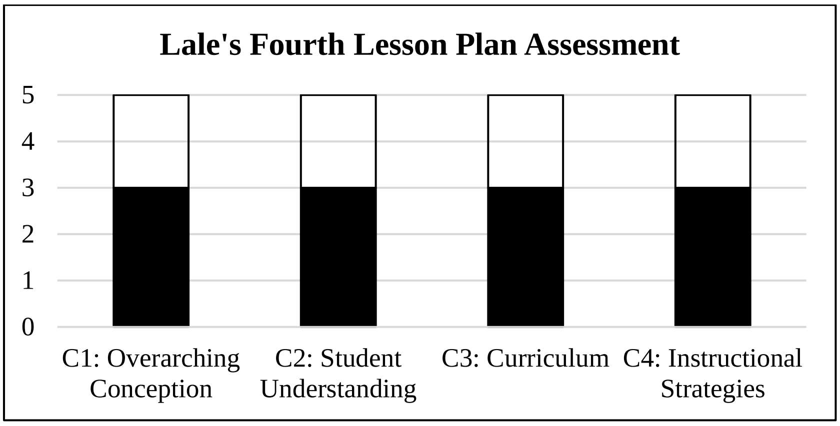

Figure 4.40 Lale's Fourth Lesson Plan Assessment

Nazım used a website including the information and mini activities about the digestive system for his last lesson plan. The teacher started the lesson by directing students to a web page about the digestive system. On that web page, students were required to prepare a model of the digestive system. They tried to identify the organs of the digestive system by reading explanations about them and their functions. After students finished their models, the teacher asked them which organs were included in their models and why. If they included an unrelated organ, the teacher guided them to the correct model with the help of questions and hints. At the end, the teacher summarized the topic and explained the correct model for the digestive system. Students also completed a quiz available on the web page and e-mailed the pdf file of their model to their teachers. In this plan, students used technology to learn new information on their own. They determined which organs to include in their models. However, the selected technology did not allow them to see whether their model would work or not. Selected technology was aligned with the curriculum but did not present any features other than information about the functions of organs and visualization. For these reasons, this plan was scored at the *Adapting (3)* level for all components of the TPACK levels rubric (Figure 4.41). Nazım mentioned in the interview that "typically this topic was taught using a human model by teacher demonstrations. It is not possible to provide each student with a model, so this web page helped me make my lesson more student-centered". Even though students used technology to prepare a model, technology did not contribute significantly to student learning.

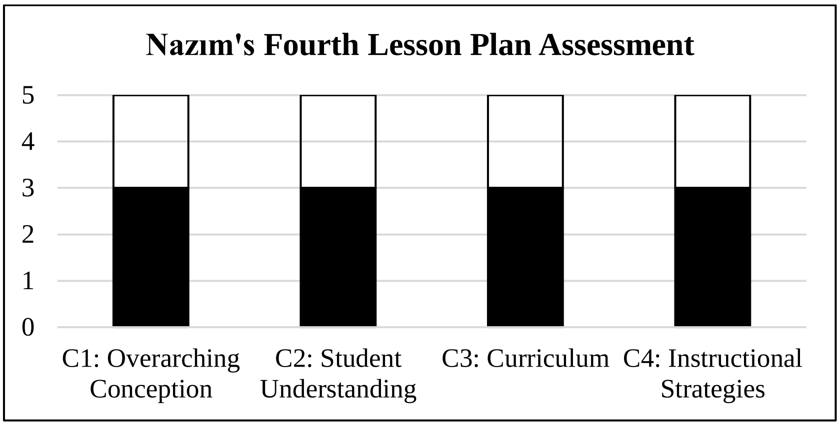

Figure 4.41 Nazım's Fourth Lesson Plan Assessment

Tomris used selected the topic of mitosis and meiosis and the method of role-playing for her last lesson plan. They already had some prior knowledge about the topic. In this lesson, students were divided into two groups to represent mitosis and meiosis. Then, they were given time to prepare a play to represent mitotic and meiotic divisions. They searched about their topic using the list of resources (animations, videos, web pages etc.) provided by their teacher. After each group performed their play, the teacher created a discussion environment about the topic and asked students about the differences between mitosis and meiosis. Lastly, she showed an animation to summarize the topic. In addition, she recorded their plays and uploaded them to the class page. Students were assigned to watch each group's video and comment on it as homework. In this plan, students were in charge of their learning. The teacher did not put any restrictions, and she just provided a list of web sources to help them reach the correct information. Students used technology on their own to learn the topic in depth to be able to represent it in a role-play. The teacher changed the way this topic is generally taught with the help of technology. For these reasons, this plan was scored at the *Exploring (4)* level for all components of the TPACK levels rubric (Figure 4.42). In the interview, she mentioned that "by recording their plays I wanted to make them watch and assess their performance as well as their friends'. Watching those videos can help them realize if there is anything wrong or missing". She used technology to make students construct their own knowledge as well as give them a chance to reflect on their own learning.

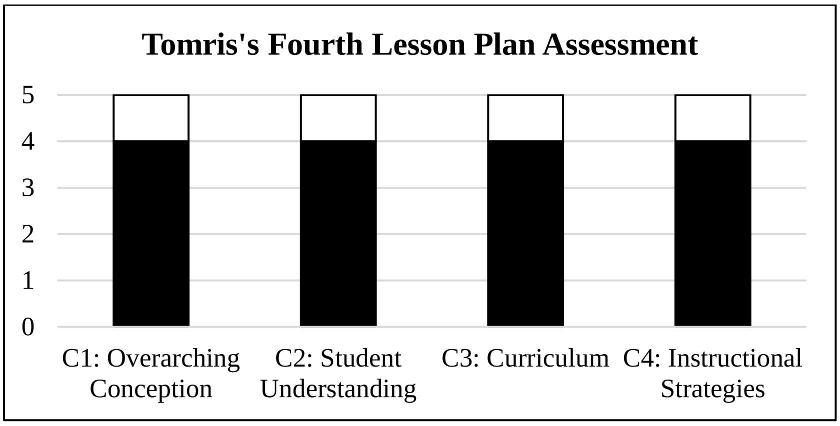

Figure 4.42 Tomris's Fourth Lesson Plan Assessment

Gülten used a simulation, an online game, and an interactive lesson platform to teach the topic of the digestive system. Using the interactive lesson platform, she monitored the students throughout the lesson. At the beginning of the lesson, students used the simulation to learn about the functions of the digestive system organs and the nutritional value of specific foods. Then, using the simulation, they were instructed to put the organs in the right order to construct a model of the digestive system. Then, they tested their system to observe if it was working or not based on the data provided by the simulation about the percentage of water and calories absorbed. After they finished their exploration, the teacher asked students questions about the correct order of the organs and their functions. After the classroom discussion, the students were directed to an online game in which they were asked to put digestive system organs in their right place on the human body. In this plan, students find the right model of the digestive system on their own by constructing their own models and testing them. The teacher changed the traditional way of teaching with the help of technological tools to make her lesson more student-centered. Students were the primary user of technology to learn new information and the teacher acted as a guide, not a director. For these reasons, this plan was scored at the *Exploring (4)* level for all components of the TPACK levels rubric (Figure 4.43). In the interview, she stated that "I would have used these technologies to teach this topic even if it was not a course requirement. They enrich the teaching process, make students more active, and support student learning". In this plan, she selected effective technologies to teach this topic and combined them with an appropriate teaching method to design a student-centered science lesson.

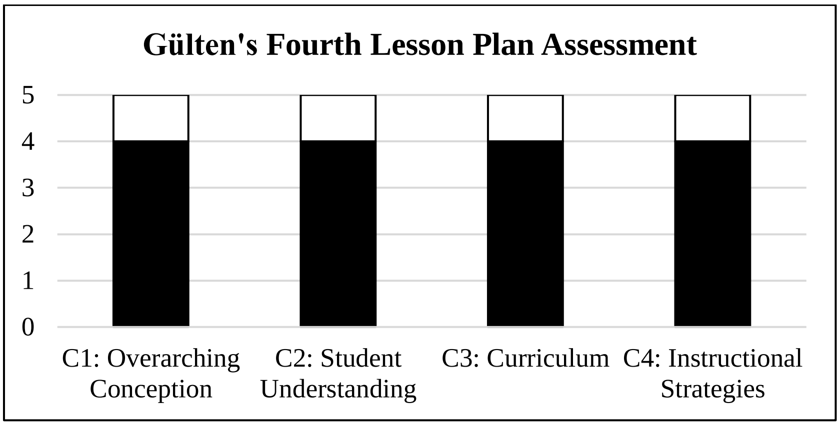

Figure 4.43 Gülten's Fourth Lesson Plan Assessment

Özdemir used the 5E learning cycle teaching method to teach about the classification of bones. After the teacher checked prior knowledge and reminded important concepts, the student groups used an augmented reality application to investigate the bone structure. They were instructed to come up with a classification schema for bones. After the groups finished their explorations, the teacher asked them to write their classifications on online spreadsheets. Then, the teacher showed the spreadsheet on the smart board and started a classroom discussion. Each group explained their classification system. Then, the teacher tried to guide them to the correct classification with the help of questions and hints. At the end, the teacher explained the groups of bones and gave examples. Lastly, using the interactive lesson platform, she showed some bone pictures and asked them to write the name and group of that bone. In this plan, a technology-based inquiry task was designed for students. Students used technology to make explorations about the topic, make observations, and draw conclusions. Students were required to come up with their own classification schema. In this plan, students were the primary user of technology for the exploration of a new topic. The teacher identified an important topic from the curriculum and enriched it with the help of technology. For these reasons, this lesson plan was scored at the *Exploring (4)* level for *C1-Overarching Conception* and *C3-Curriculum* components (Figure 4.44). *For C2-Student Understanding* and *C4-Instructional Strategies* components, this plan was scored as transitioning from *Exploring* to *Advancing* (4.5) because the teacher prepared technology-based tasks to promote high-level thinking; students asked questions, collected data, justified their explanations, and discussed with each other to draw conclusions. In the interview, he stated that “without technology, the students cannot get a chance to individually observe an actual human model; the lesson will be teacher-directed. At best, the teacher can explain the topic using a model or a poster”. He selected an appropriate technology for the chosen topic and enriched his lesson with the help of it. He facilitated students’ high-level thinking with technology.

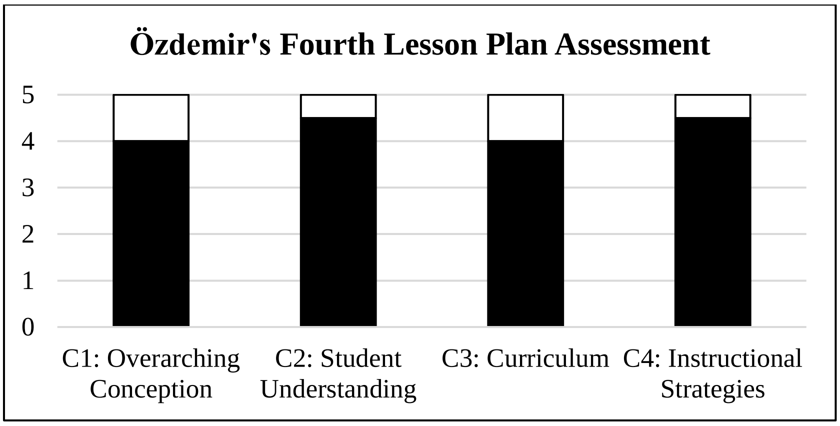

Figure 4.44 Özdemir's Fourth Lesson Plan Assessment

In his last lesson plan, Cemal selected a simulation to teach about flower pollination. First, students used the simulation to learn about the parts of flowers. Students were asked to read the explanations and label each part. The simulation provided feedback about correct and incorrect answers. After they labeled each part correctly, learned about their functions, and filled out their worksheets, they were asked to simulate the processes of self-pollination and cross-pollination using the simulation. The simulation provided information about the steps of pollination while students were doing it. After they finished their exploration, they were asked to explain the steps of each type of pollination, compare them and write down their differences on their worksheets. Then, the teacher started a classroom discussion about pollination. After students finished their discussion, the teacher summarized the topic. In this plan, students used technology to learn the topic on their own, explored with the simulation to observe natural phenomena, discussed their observations, and analyzed their observations to identify similarities and differences. The selected technology was aligned with curriculum goals. The teacher used a student-centered pedagogy instead of using a teacher-centered approach to deliver information. For these reasons, this plan was scored at the *Exploring (4)* level for all components of the TPACK levels rubric (Figure 4.45). In the interview, he stated that “I found two simulations about this topic; however, the other one did not allow the students to explore anything. It was more like an animation explaining the topic”. He selected an appropriate technology for a student-centered lesson and supported it with the worksheet he prepared.

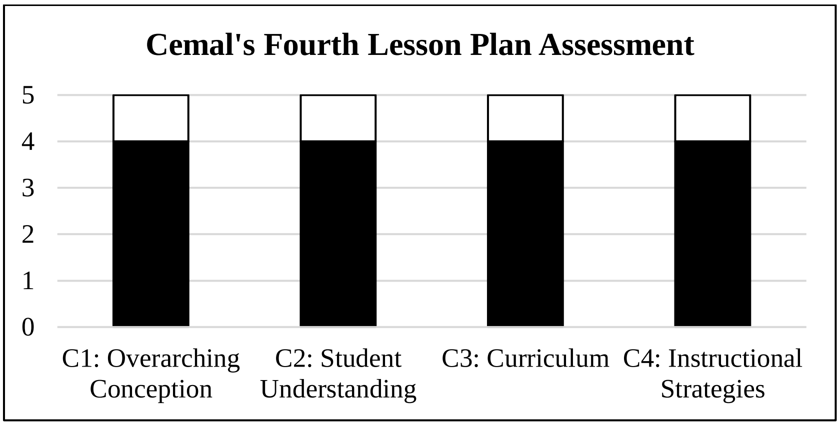

Figure 4.45 Cemal's Fourth Lesson Plan Assessment

Nilgün used an online inquiry space to gather different technologies on one platform and present them to students. First, student groups explored the free fall of heavy and light objects in air and vacuum atmosphere with or without parachutes and were asked to explain their observations. Then, the teacher asked what would happen if they were dropped from an inclined plane. Students were directed to a simulation in which they could change the angle of incline, friction, and weight of the object. Students were asked to write their own research questions and investigate them using the simulation. They were instructed to use a digital canvas to document their research process. After each group finished, they presented their findings and conclusions. In this plan, students were totally in charge of their learning. The teacher presented them with appropriate technologies, and they decided how to use them. No instructions or limitations were given to the students, and they were engaged in an open-inquiry with the help of technology. The students manipulated the variables and observed the consequences using the data tables and graphics provided by the simulation. In addition, they were required to explain their process of investigation and justify their conclusions. Technology-based activities were fully aligned with curriculum goals and promoted high-level thinking and conceptual understanding. For this reason, this plan was scored at the *Advancing (5)* level for all components of the rubric (Figure 4.46). In the interview, she stated that "the simulations provided accurate data for students to correctly observe the relationship between variables. We cannot do these experiments in a school environment accurately". She prepared an open-inquiry activity for her students and selected effective technologies to support their learning process.

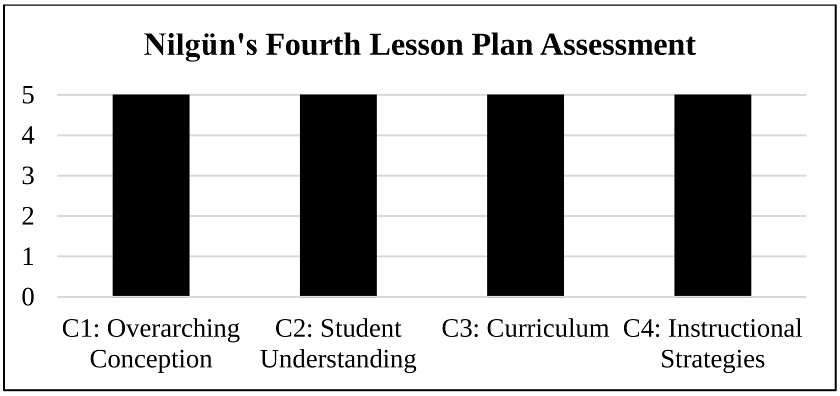

Figure 4.46 Nilgün's Fourth Lesson Plan Assessment

The assessment of the fourth and last lesson plans of first cycle participants revealed that four of the participants were at the *Exploring* level. Only two participants were at the *Adapting* level for all components. None of the lesson plans were scored at the *Recognizing* and *Accepting* levels for any of the components. One participant was scored at the *Advancing* level for all of the components. Table 4.27 presents the assessment of the fourth lesson plans across the components of the TPACK levels rubric for all participants of the first cycle.

Table 4.27

Assessment of the Fourth Lesson Plans (Cycle-1)

Participant	C1: Overarching Conception	C2: Student Understanding	C3: Curriculum	C4: Instructional Strategies
Lale	3.0	3.0	3.0	3.0
Nazım	3.0	3.0	3.0	3.0
Tomris	4.0	4.0	4.0	4.0
Gülten	4.0	4.0	4.0	4.0
Özdemir	4.0	4.5	4.0	4.5
Cemal	4.0	4.0	4.5	4.0
Nilgün	5.0	5.0	5.0	5.0

4.3.4.2. Assessment of Fourth Lesson Plans (Cycle-2)

In this section, findings related to the fourth and last lesson plans of second cycle participants are explained. The main components of the fourth lesson plans selected by participants are presented in Table 4.28.

Table 4.28

Main Components of Cycle-2 Participants' Fourth Lesson Plans

Participant	Content	Pedagogy	Technology
Umay	Acids and bases	POE	Simulation, quiz tool
Birhan	Plant growth	5E – Learning cycle	Video, simulation
Turgut	Levers	5E – Learning cycle	Simulation
Didem	Weight and mass	Laboratory work	Simulation
Ayten	Greenhouse effect	5E – Learning cycle	Simulation, video

Umay used the POE strategy to teach students acids and bases. First, the teacher reminded the definitions of acids and bases. Then, students were given a list of materials and asked to predict whether they were acid or base. Then, the teacher collected their predictions and directed them to a simulation to measure the pH value of the materials. They determined whether the substance was acid or base based on the pH value provided by the simulation. After students' determined the pH value of all substances, the teacher asked about the discrepancies between their predictions and observations. Students were also asked about the common characteristics of acids and bases according to their observations. Lastly, the teacher used an online quiz tool to make a quiz. In this plan, students used technology to replicate a traditional classroom experiment. Even though technology based tasks were aligned with the curriculum goals, they were too structured and limited. Technology only supported a basic understanding of the topic. For these reasons, this plan was scored at the *Adapting (3)* level for all components of the TPACK levels rubric (Figure 4.47). In the interview, she stated that "I used this technology because it gives students a chance to learn pH values of various substances from daily life. It would be difficult to make this experiment in class with that many substances". As she confirmed, she just used technology to replicate a simple experiment to increase the number of substances to be tested. Technology integration did not support students' high-level thinking skills.

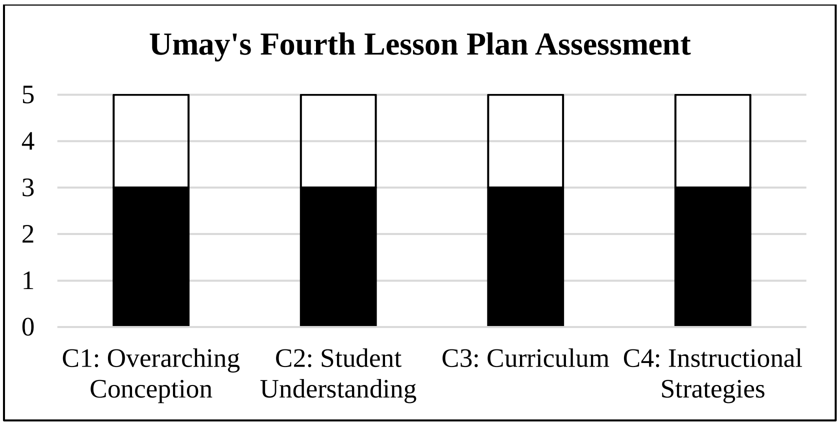

Figure 4.47 Umay's Fourth Lesson Plan Assessment

In order to teach the topic of plant growth, Birhan used the 5E learning cycle teaching method and various technological tools. First, the teacher used a macro time-lapse video showing plant growth. Then, student groups were given V-diagram sheets and asked to plan an experiment about the factors affecting plant growth. The teacher directed them to a simulation where they could manipulate variables such as intensity of light, water level, fertilizers and speed up the time to observe their effect on plant growth. After they finished their explorations, each group presented their process of investigation and results to the class. In this plan, students were not given cookbook instructions about what to do with technology, and they decided on their own method of investigation. They were engaged in an open-inquiry activity. They decided on their independent, dependent, and controlled variables and observed the results of their actions with the help of graphics and data tables provided by the simulation. They were required to justify their conclusions during classroom discussions. Technology-based activities were fully aligned with curriculum goals and promoted high-level thinking and conceptual understanding. For these reasons, this plan was scored at the *Advancing (5)* level for all components (Figure 4.48). In the interview, she stated that "this simulation allowed students to manipulate and control variables on their own. I found other simulations related to this topic, but they were directing students on what to do. I selected this one to give students the freedom to determine their process". She was able to select a technology that could be effectively combined with her pedagogy and content to prepare an open-inquiry activity.

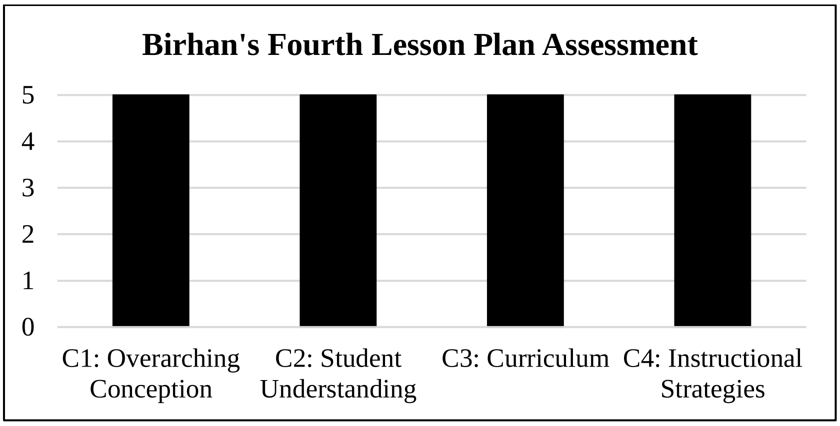

Figure 4.48 Birhan's Fourth Lesson Plan Assessment

In his last lesson plan, Turgut used a simulation to teach about levers. After checking students' prior knowledge about simple machines, the students were given worksheets and directed to a simulation. In this worksheet, students were guided to collect data about the amount of force needed to lift different objects using a lever. There were also questions about the relationship between the position of the object and the amount of force needed. Students also explored second-class and third-class levers using the simulation with the help of guiding questions. At the end of each activity, the teacher asked for their observations and helped them reach meaningful conclusions. In this plan, a guided inquiry activity was presented to students. With the help of worksheets, the teacher guided students' explorations with technology. Students made observations, collected data under different circumstances, and drew conclusions. Technology based activities were aligned with curriculum goals and concentrated on doing science. For these reasons, this plan was scored at the *Exploring (4)* level for all components of the TPACK levels rubric (Figure 4.49). In the interview, he mentioned that "there are many variables to be investigated about levers. I prepared the worksheet with guiding questions to make sure all students made observations related to each of these variables". He used both teacher-directed and student-centered strategies while using technology to make sure students explored the topic from all necessary aspects.

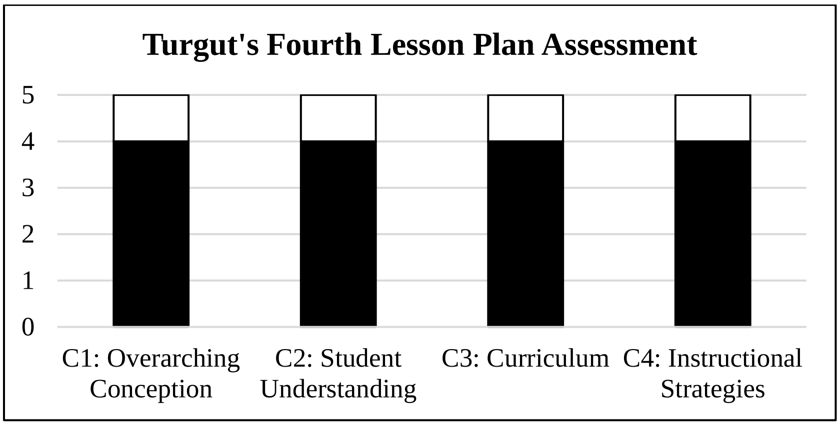

Figure 4.49 Turgut's Fourth Lesson Plan Assessment

In her fourth and last lesson plan, Didem selected a simulation to teach about weight and mass. First, the teacher gave brief definitions of force, weight, and mass. Then, students used a simulation to explore the concepts of mass and weight using spring scales and balances. First, they were guided to explore how a balance works and what it measures with different activities and questions given in the worksheets. Then, they were instructed to take measurements with a spring scale on Earth, Moon, Mars, and Jupiter and record their observations. Lastly, they used balance on different planets to observe whether the mass of objects changed or not. After they finished their explorations, the teacher asked their observations and conclusions to start a classroom discussion about mass and weight. In this plan, students used technology to explore the concepts of mass and weight on their own. Technology allowed them to collect data under different circumstances. With the help of worksheets, students were guided to make predictions, collect data and draw conclusions. The teacher used a student-centered approach to teach the topic, and technology-based tasks were aligned with curriculum goals. For these reasons, this plan was scored at the *Exploring (4)* level for all components of the TPACK levels rubric (Figure 4.50). In the interview, she stated that "mass and weight are difficult concepts for students to understand without active explorations; however, we cannot change gravity in the classroom for students to explore its effect on weight". She was able to identify an important science topic and improve the traditional way of teaching it.

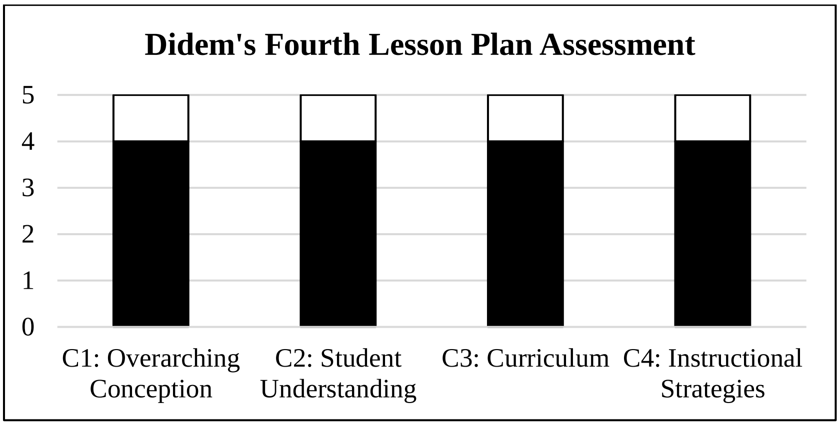

Figure 4.50 Didem's Fourth Lesson Plan Assessment

Ayten selected the topic of the greenhouse effect as content and a simulation as the main technology. First, students watched a video about greenhouse gases. Then, they formed groups and used a simulation to investigate the effect of greenhouse gases on temperature. Students changed the percentage of greenhouse gases and collected data using the tables and graphs provided by the simulation. They made observations about the temperature, the amount of heat flowing into the atmosphere, and the amount of heat flowing out of the atmosphere. In the end, a classroom discussion was held about students' observations and interpretations. In this plan, students used technology to speed up a natural phenomenon, manipulate variables and collect data under different circumstances. The teacher guided them during their explorations; however, she did not direct them on what to do. Technology based tasks were aligned with the curriculum and promoted students' conceptual understanding. For these reasons, this plan was scored at the *Exploring (4)* level for all components of the TPACK levels rubric (Figure 4.51). In the interview, she stated that "without this technology, students cannot collect accurate data about this phenomenon, and the concepts will remain abstract for them. With this simulation, they get a chance to speed up time, make observations, and see graphical representations of the data produced". She identified a topic that would be difficult to teach without technology integration. With the help of technology, she made students actively explore the topic, make observations and draw conclusions.

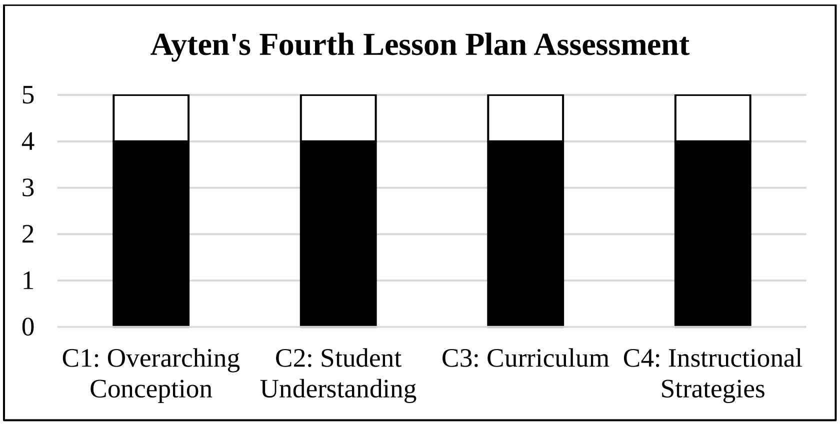

Figure 4.51 Ayten's Fourth Lesson Plan Assessment

The assessment of second cycle participants' fourth lesson plans revealed that three of the participants were at the *Exploring* level. None of the lesson plans were scored at the *Recognizing* and *Accepting* levels for any of the components. One participant was scored at the *Advancing* level, and one participant was at the *Adapting* level for all components. Table 4.29 presents the assessment of the fourth lesson plans across the components of the TPACK levels rubric for all participants of the second cycle.

Table 4.29

Assessment of the Fourth Lesson Plans (Cycle-2)

Participant	C1: Overarching Conception	C2: Student Understanding	C3: Curriculum	C4: Instructional Strategies
Umay	4.0	4.0	4.0	4.0
Birhan	5.0	5.0	5.0	5.0
Turgut	4.0	4.0	4.0	4.0
Didem	3.0	3.0	3.0	3.0
Ayten	4.0	4.0	4.0	4.0

4.3.4.3. Summary of the Findings for Fourth Lesson Plans

The lowest score received across the components of the TPACK levels rubric determines participants' overall TPACK level. Figure 4.52 presents the distribution of participants from both cycles across different levels for the components of the TPACK levels rubric and overall TPACK level.

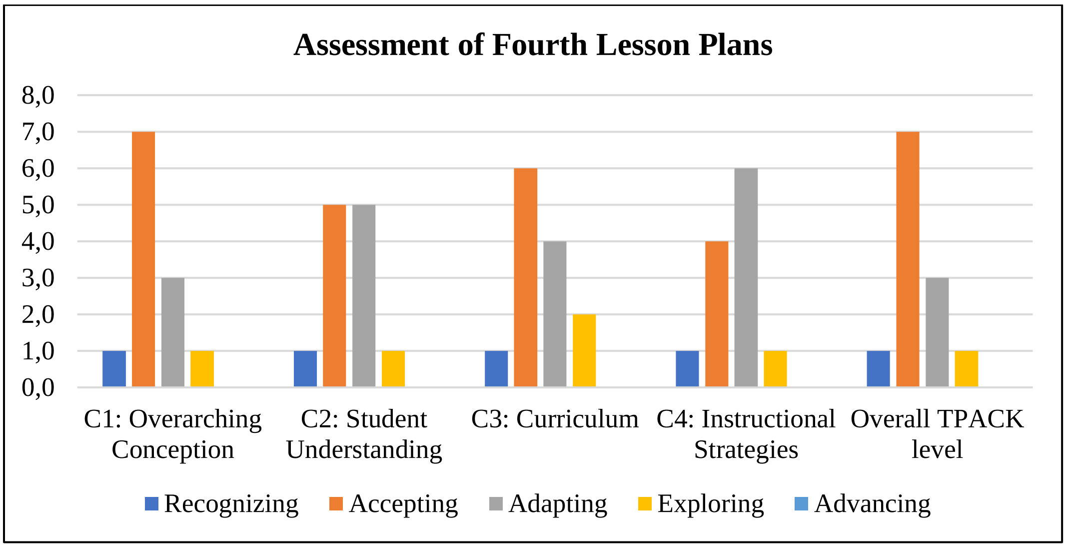

Figure 4.52 Assessment of Participants' Fourth Lesson Plans

At the end of the course, two participants from one cycle (Nazım and Lale) and one participant from the second cycle (Umay) were at the *Adapting* level. All of them were also at this level at the end of the *Application* stage. In their last lesson plans, all of them selected technologies that did not give students a chance to develop their own strategies to actively explore the topic. Students were given low-level thinking activities with technology.

Seven participants (four from the first cycle and three from the second cycle) were at the *Exploring* level at the end of the course. Three of them (Tomris, Turgut, and Didem) were also at this level at the end of the *Application* stage. Three of them (Gülten, Özdemir, and Cemal) increased their level from *Adapting* level, and one of them (Ayten) increased their level from the *Accepting* level. All of their last lesson plans included guided inquiry activities for students to form the hypothesis, collect data and draw conclusions. They used a student-centered pedagogy to teach with technology.

Two participants (Nilgün and Birhan), one from each cycle, were scored at the *Advancing* level for all of the components. Both of them were scored at the *Exploring* level at the end of the *Application* stage and increased their level of TPACK. In their last lesson plans, they prepared open-inquiry activities where students determined their own research questions to be investigated, their method of investigation and were required to explain their results and conclusions. The teacher did not interfere with the students' process of investigation.

4.3.5. Change in Participants' Level of TPACK Throughout the Course

Participants' levels of TPACK were determined using the four lesson plans they submitted throughout the course: (1) submitted at the beginning of the course; (2) submitted at the end of the *Theory* stage; (3) submitted at the end of the *Application* stage; (4) submitted at the end of the *Practice* stage. Details of these lesson plans and their assessment were explained in the previous sections.

There were seven participants in the first cycle of implementation. Three of them started the course at the *Recognizing* level; two of them (Lale and Nazım) finished at the *Adapting* level (progressed two levels), and one of them (Tomris) finished at the *Exploring* level (progressed three levels). Two of the participants (Gülten and Özdemir) started the course at the *Accepting* level and finished at the *Exploring* level (progressed two levels). Cemal started the course at the *Adapting* level and finished at the *Exploring* level (progressed one level). Lastly, Nilgün started at the *Exploring* level and finished at the *Advancing* level. Figure 4.53 presents the first cycle participants' level of TPACK at different points.

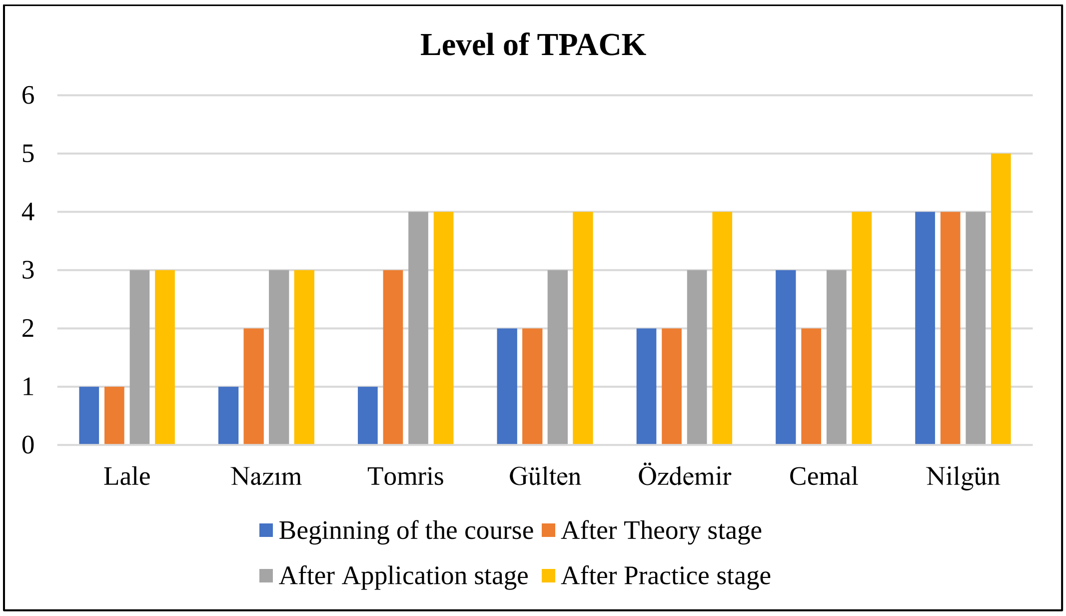

Figure 4.53 Change in First Cycle Participants' Level of TPACK

There were five participants in the second cycle of implementation. Three of them started the course at the *Accepting* level; Umay finished at the *Adapting* level (progressed one level), Turgut finished at the *Exploring* level (progressed two levels), and Birhan finished at the *Advancing* level (progressed three levels). Ayten and Didem both started the course at the *Adapting* level and finished at the *Exploring* level (progressed one level). Figure 4.54 presents second cycle participants' level of TPACK at different points.

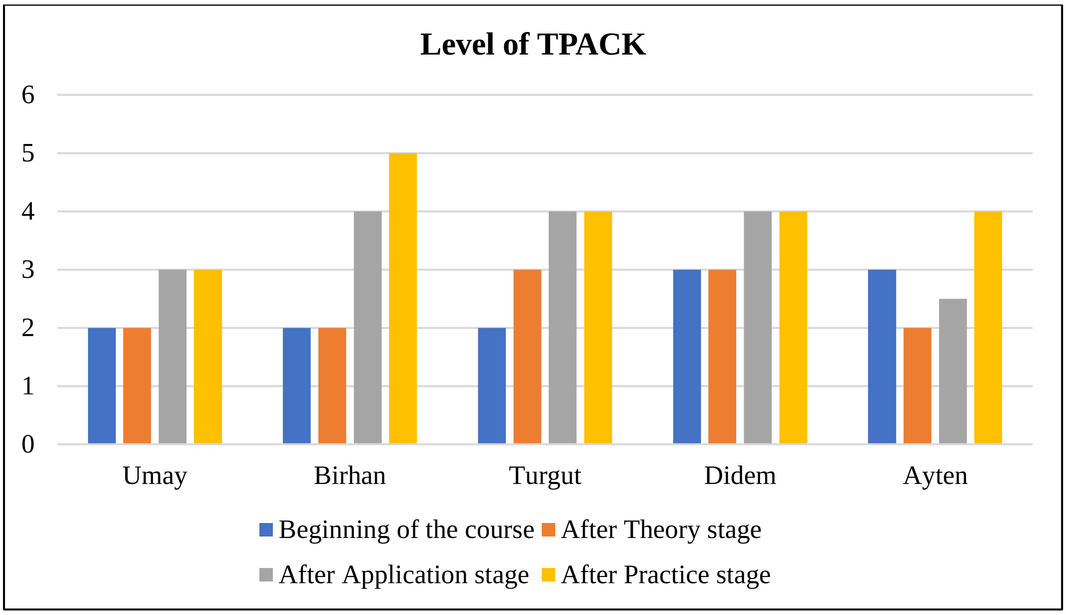

Figure 4.54 Change in Second Cycle Participants' Level of TPACK

Based on the analysis of lesson plans submitted by participants during both cycles of implementation, it was seen that after attending the *Teaching Science with Technology* course based on T-A-P course design, all of the participants' levels of TPACK progressed at different levels in both cycles of implementation.

CHAPTER 5

DISCUSSION

The main purpose of the present study was to develop a course design to be implemented in Teaching Science with Technology graduate course and investigate its influence on science teachers' TPACK. The proposed design was implemented in two iterative cycles. To investigate its effectiveness for TPACK development of science teachers, the following research questions were answered:

1. What were graduate science education students' ideas about *Teaching Science with Technology* course based on T-A-P course design?
2. Is there a change in graduate science education students' perceived competencies and self-efficacy of TPACK after attending the *Teaching Science with Technology* course based on T-A-P course design?
3. How did graduate science education students' level of TPACK change as they attended the *Teaching Science with Technology* course based on T-A-P course design?

In this chapter, the findings for each research question are discussed in the following sub-sections. Lastly, implications for practice and suggestions for future research are explained.

5.1. Participants' Views on the T-A-P Course Design

Design-based research requires the testing, evaluating, and revising of the proposed design. In the present research, the effectiveness of the design was evaluated based on participants' TPACK development and participants' feedback. T-A-P course design was implemented for two semesters, and participants of the study were asked to write weekly feedback about each class meeting. In addition, at the end of the semester, they were asked to write general feedback about the course.

The first principle employed while designing the T-A-P course design is: Building a theoretical foundation is important for teachers' TPACK development. In their feedback, participants mentioned that reading articles and discussing them in the classroom helped them understand the TPACK framework. They stated that especially well-designed presentations and the integration of discussion questions prepared by them were really helpful in terms of improving their understanding of principles of effective technology integration. In addition, participants also stated that in-class activities about the theoretical framework of TPACK (e.g., defining components of the framework, identifying teacher competencies for technology integration, TPACK game) also supported their understanding of TPACK.

In fact, at the beginning, the researcher did not plan an in-class activity for each week of the Theory stage. It was just planned for the first week's lesson as a warm-up activity. However, after the first week of the first cycle of implementation, two participants mentioned that this activity was very helpful in terms of increasing their participation and there should be more activities like that. This suggestion was taken into consideration, and in-class activities were added to each class meeting during the Theory stage starting from the first cycle of implementation. In design-based research, "participants are not subjects assigned to treatments but instead are treated as co-participants in both the design and even the analysis" (Barab & Squire, 2004, p.3). This instant was an example of how participants can be involved in refining the proposed design.

Learning about theories of technology integration is thought to be effective for the development of teachers' TPACK (Baran & Uygun, 2016; Lee & Kim, 2014; Tondeur et al., 2012). Participants' feedback also supported this view. They reflected on their TPACK development in their feedback and emphasized the importance of gaining a theoretical perspective to be able to understand what constitutes effective technology integration. In addition, participants stated that learning theories of TPACK before learning about different technological tools helped them examine technological tools with an informed perspective and identify their affordances, limitations, and educational uses.

The second principle guiding the development of the T-A-P course design is: Examining examples of technology-integrated learning materials promotes teachers' development of TPACK. For this reason, participants were presented with example technology-integrated lesson plans and also assigned to examine each other's lesson plans available in the LMS. In their feedback, participants commented positively on the examination of example lesson plans. They stated that it helped them concretize the interdependence aspect of technology, pedagogy, content, and context components. Examining examples of technology-integrated learning materials was also suggested in the literature to promote teachers' TPACK development by giving them a chance to explore how technology can be combined with particular teaching methods to teach a particular subject (Baran & Uygun, 2016; Mouza et al., 2014). Participants' feedback supported the suggestions given in the literature.

The third principle of the T-A-P course design is: Investigation of technologies using the technology mapping approach promotes the TPACK development of teachers. Angeli and Valanides (2009; 2013) suggested using technology mapping approach when investigating technologies to improve teachers' TPACK. In their feedback, participants stated that identifying the affordances, limitations and potential uses of technologies was effective for their TPACK development. Participants also mentioned that investigating technologies on their own is more effective than learning them through direct instruction. They also mentioned that discussions about the integration of technologies were helpful in enhancing their TPACK. Almost all of the participants expressed that the examination of different technologies increased their technological knowledge.

Participants' views were consistent with the study of Angeli and Valanides (2013). In their study, the researchers investigated the effectiveness of technology mapping by giving Excel-based tasks to pre-service teachers and asked them to explain the affordances and limitations of Excel. The results revealed that technology mapping is effective in helping teachers combine their knowledge of content, pedagogy, and technology in a meaningful way. In addition, participants of that study also commented on the technology mapping approach and suggested its use in teacher education programs.

The fourth principle of the T-A-P course design is: Designing technology-enhanced learning materials improves teachers' TPACK. Preparing lesson plans was not mentioned frequently by the participants in their feedback because it was considered as an assignment of the course rather the being part of the instruction. However, in the last interview, when asked specifically about whether the number of lesson plan assignments should be decreased, all participants stated that they were effective for their TPACK development and, therefore, should be conserved. Literature also consistently showed that design activities promote TPACK development (Baran & Uygun, 2016; Koehler et al., 2005; Lee & Kim, 2014; Voogt et al., 2016). Participants of this study agreed with this idea by stating that preparing lesson plans helped them practice combining technology, pedagogy, and content in a meaningful way and increased their level of TPACK.

The fifth principle guiding the T-A-P course design is: Implementing technology-integrated lesson plans and reflecting on the experiences contribute to the development of TPACK. Participants of this study stated that micro-teachings were helpful for improving their TPACK by experiencing the implementation of technology integrated science lessons. Participants also expressed that micro-teachings helped them reflect on their performance and assess their own development. In addition, observing each other's micro-teachings was also found to be effective in terms of gaining different perspectives and experiencing a technology-integrated science lesson as a student. Researchers also suggest the use of micro-teachings for the development of TPACK since micro-teachings help teachers identify their strengths and weaknesses when teaching with technology and assess their performance (Baran & Uygun, 2016; Lee & Kim, 2014). As supported by the feedback of participants, experiencing the teaching of a technology integrated lesson is important for TPACK development.

The last principle of the T-A-P course design is: Expert feedback as well as feedback from peers are important for developing teachers' technology integration skills (Angeli

& Valanides, 2009; Tondeur et al., 2012; Lee & Kim, 2014). Participants of the study received feedback from their peers and the instructor for each of their lesson plans; however, they did not explicitly mention this process in their written feedback about the course design. Some participants mentioned the feedback for micro-teaching as being informative to assess the quality of their lesson design. Most probably, since receiving feedback on lesson plans from the instructor is common in their teacher education programs, they did not feel the need to comment on them as a course design element.

In summary, as suggested in the literature, courses that target TPACK as a whole, not focusing on some of its components, are helpful for teachers' development of TPACK (Chai et al., 2010; Lyublinskaya & Tournaki, 2014). T-A-P course design included various activities and strategies for this purpose, and findings for participants' feedback about course design revealed that the identified principles for T-A-P course design were helpful for the TPACK development of participants. The activities that required the application of their newly gained knowledge and skills into specific situations were appreciated by participants.

5.2. Change in Participants' Perceived Competencies and Self-Efficacy of TPACK

In the present study, the change in participants' perceived competencies and self-efficacy of TPACK after attending the *Teaching Science with Technology* course based on T-A-P course design was investigated with the help of two scales: TPACK-Deep (Kabakçı-Yurdakul et al., 2012) and TPACK-SeS (Canbazoğlu-Bilici et al., 2013). The results revealed significant improvements in participants' scores for both of the scales in both cycles of implementation.

All of the participants' total scores of perceived competencies of TPACK, as measured by TPACK-Deep scale (Kabakçı-Yurdakul et al., 2012), increased after taking the *Teaching Science with Technology* course. In the first cycle of implementation, at the beginning of the course, one participant had a low level of TPACK, four participants had a medium level of TPACK, and two participants had a high level of TPACK. At the end of the course, all of the participants had a high level of TPACK. In the second cycle of implementation, at the beginning of the course, one participant had a medium level of TPACK, and four participants had a high level of TPACK. At the end of the course, the participant with a medium level of TPACK also had a high level of TPACK, and the other participants increased their total scores. Relevant literature suggests that perceived ICT competence can be influenced by contextual factors as well as personal factors, and it can influence teachers' intention to use technology (Wang & Zhao, 2021). This is also reflected in the present study, and participants started the course with different levels of perceived TPACK competencies. In addition, it was suggested that with successful interventions designed to improve TPACK, perceived competencies could also be improved (Ersoy et al., 2016). The findings of the present study were also consistent with the literature; all participants' perceived TPACK competencies increased after taking the course, implying that the *Teaching Science with Technology* based on T-A-P course design was effective for improving graduate science education students' TPACK competencies.

Participants' self-efficacy, as measured by TPACK-SeS (Canbazoğlu-Bilici et al., 2013), also significantly increased at the end of the first cycle of implementation. However, at the end of the second cycle, the increase in participants' self-reported self-efficacy was not statistically significant. To investigate this, all participants' individual scores were examined and it was seen that all participants' scores increased from pre-administration to post-administration except one participant, Birhan. The pre-administration scores of Birhan were very high (ranged between 96 and 100). Even though Birhan's post-administration scores were very high (ranged between 88 and 96), there was a decrease when compared to pre-administration. This might be a result of increased knowledge and awareness of effective technology integration. Before the course, the participant might have answered the survey with a superficial understanding of technology integration. At the end of the course, the participant might have gained the required perspective to explain and detect her shortcomings and deficiencies regarding technology integration. Gaining the ability and knowledge for self-assessment of TPACK can also be considered as an achievement for that participant.

Relevant literature suggests that TPACK self-efficacy influences teachers’ technology use practices in their classrooms and can be improved through interventions engaging teachers in design activities (Yerdelen-Damar et al., 2017). Consistent with the relevant literature (Lee & Lee, 2014; Kapıcı & Akçay, 2020), in the present study, participants’ TPACK self-efficacy was developed as they were engaged in various activities specifically designed to improve their TPACK.

In essence, both TPACK-Deep scale and TPACK-Ses were designed to measure participants’ self-reported beliefs about their abilities to integrate technology; however, the frameworks and approaches used while designing the scales were different. The results revealed that participants’ perceptions regarding their TPACK have improved after attending the *Teaching Science with Technology* course based on T-A-P course design. The guiding principles of the course design were determined based on the existing literature, and course activities were designed accordingly to improve participants’ TPACK. Other intervention studies investigating participants’ TPACK development also yielded similar results. Engaging in design activities (Chai & Koh, 2017; Ersoy et al., 2016; Tondeur et al., 2012), performing micro-teachings (Danday, 2019; Voogt et al., 2013), investigating technologies, and discussing their implications (Angeli & Valanides, 2013) are effective strategies for the development of TPACK.

The results regarding self-reported measures of TPACK implied that T-A-P course design was effective in terms of developing teachers’ TPACK self-efficacy and competencies. However, self-reported measures are not enough to draw a final conclusion about participants’ TPACK development. For this reason, participants’ lesson plans were also used to assess TPACK development throughout the course.

5.3. Change in Participants’ Level of TPACK

In order to assess the development of TPACK as participants’ progressed through stages of the T-A-P course design, lesson plans were used. Participants prepared four technology integrated lesson plans; one lesson plan at the beginning of the course and three lesson plans at the end of each stage. There were no restrictions regarding the selection of content, pedagogy, and technology for participants. The lesson plans were analyzed by using the TPACK Levels Rubric developed by (Lyublinskaya & Tournaki, 2012). Participants' TPACK level was assessed among four components: overarching conception, knowledge of students' understandings, knowledge of curriculum, and knowledge of instructional strategies. For each component, participants are rated among five levels of TPACK proposed by Niess et al. (2006): recognizing, accepting, adapting, exploring, and advancing. Based on the lesson plan analysis, it can be said that all of the participants increased their level of TPACK at the end of the course in different degrees.

At the beginning of the course, most of the participants were at the recognizing and accepting levels implying that they did not have the required knowledge and skills for effective technology integration. At these levels, teachers generally use teacher-directed pedagogical strategies and use technology for motivation, student practice, and/or teacher demonstrations. Teachers' knowledge at these levels is composed of distinct bodies of knowledge for technology, content, and pedagogy; teachers need experiences about teaching a particular content with technology and using effective pedagogical strategies to facilitate student explorations with technology to transform their knowledge to TPACK (Niess, 2013). Consistent with the previous studies, this result showed that their undergraduate education did not prepare them for effective teaching of science with technology (Lyublinskaya & Tournaki, 2013).

There were only a few participants at the adapting level at the beginning of the course. At the adapting level, teachers try to integrate technology into their teaching; however, at best, they can prepare low-level activities managed by the teacher (Niess, 2012). It can be said that teachers at this level have begun to transform their knowledge of content, pedagogy, and technology into TPACK, yet, they need future experiences about the affordances of technology to support student learning and improve their teaching practices.

There was only one participant at the exploring level, Nilgün. She was a Ph.D. student in the elementary education department with a research interest in argumentation-based teaching. She was not working actively as a teacher at the time of the study but had two years of field experience. Her lesson plan included inquiry activities for students encouraging them to use technology on their own to explore the topic. Her initial level of TPACK was very high even though she had no prior training in technology integration. Having teaching experience cannot explain this result on its own since other participants with teaching experience had lower levels of TPACK. Studying argumentation-based instruction also cannot explain this result because Nazım also had a similar research background, yet, his initial TPACK level was at the recognizing level. Similarly, there were other participants with the same undergraduate education, but their initial TPACK levels were lower. Nilgün was an outlier among participants. One possible explanation may be her own personal efforts put into the preparation of the lesson plan supported by her teaching experience, research background, and undergraduate education.

Initial TPACK levels of participants revealed that most of them did not possess required knowledge and skills for effective technology integration. Literature about beginning teachers' TPACK also supports this finding. Beginning teachers with little or no experience mostly use technology for practice purposes and fail to integrate in into their teaching practices (Agyei & Voogt, 2011; Ottenbreit-Leftwich et al., 2010; Tondeur et al., 2017). Pre-service teachers and beginning teachers need hands-on experiences specifically designed to improve their TPACK.

The theory stage of the T-A-P course design was planned to build a theoretical foundation for participants regarding the effective use of technology for teaching. Even though previous research emphasizes the importance of theoretical knowledge for TPACK development, it is missing in most of the professional development studies and pre-service course designs. Most of the training programs include a short presentation about the TPACK framework. In the present study, participants were assigned to read articles, write reflections and prepare discussion questions about them, and discuss their ideas in the classroom for five weeks. At the end of this stage, participants prepared their second lesson plans.

When compared to the initial lesson plan performances, there was not a significant improvement in most of the participants' level of TPACK; the majority of them stayed at their initial level of TPACK. There were three participants whose level of TPACK increased. Two of them were at the recognizing level initially and progressed to accepting and adapting levels. One of them was at the accepting level and increased his level of TPACK to adapting. In addition, there were two participants whose TPACK level regressed from adapting to accepting at the end of the Theory stage. No consistent improvement was observed in teachers' TPACK.

According to these results, it can be concluded that having theoretical information alone does not lead to an improvement in terms of TPACK. No similar studies can be found examining the singular influence of having theoretical information about the frameworks and general principles of technology integration on improving TPACK. Previous research and reviews suggested engagement with theoretical knowledge to learn the principles of effective technology integration; however, they also stated that it should be combined with other strategies such as design experiences, exploration of technologies etc. (Baran & Uygun, 2016; Tondeur et al., 2012). As the results of the present study revealed, just learning about the theory does not lead to an improvement in teachers' TPACK. Teacher education efforts should use multiple strategies for teachers' TPACK development.

The second stage of the course was application. During this stage, participants were introduced to various technological tools and asked to determine the affordances, limitations, and potential uses of each particular tool in science teaching by working in groups and discussing their ideas as a whole class. In addition, they made a group presentation about specific technology and showed an example application. At the end of this stage, participants submitted their third lesson plans. In addition, participants performed micro-teachings using this plan.

When compared to the previous lesson plan performances, most of the participants' TPACK levels increased after examining different technologies. Only two of the participants stayed at the same level: Nilgün and Ayten. Nilgün's TPACK level was determined to be at the exploring level for all three of her lesson plans. Since her initial level of TPACK level was very high, there was very little space for improvement. Ayten's TPACK level also did not change at the end of this stage; she stayed at the accepting level. The lesson plan she prepared was problematic in terms of technology, pedagogy, and content. She tried to use an augmented reality application she learned during the application stage. The technology was appropriate for the content to be taught; however, she was not able to plan the teaching process effectively.

At the end of the application stage, all participants, except Ayten, were at the adapting and exploring levels. This means participants were able to integrate technology into their plans for teaching the subject; however, their pedagogical approaches were different. Adapting level implies that teachers use technology to replace traditional instructional practices with the integration of technology. The instructions are mostly teacher-directed at this level; even if students use technology for scientific explorations, the procedures they use are determined by the teacher with highly structured worksheets. This might be because the participants were assigned to perform micro-teachings with these lesson plans. It might be intimidating to perform a student-centered technology-integrated lesson plan. It is difficult for new teachers to teach through inquiry; it requires experience to be able to use inquiry-based teaching approaches (Kaplon-Schilis, 2018; Wang et al., 2008). They need more practice with technology as well as using it with an inquiry-based teaching approach. Teachers need long-term training to gain confidence in teaching with technology and achieve higher levels of TPACK (Koh & Divaran, 2011). Previous research also showed that even after attending professional development programs about TPACK, some teachers tend to continue traditional instructional practices while using technology for low-level activities (Lyublinskaya & Tournaki, 2011; Niess et al., 2008).

Almost half of the participants achieved exploring level of TPACK at the end of the application stage. They used student-centered instructional approaches while using technology to teach the topic. When compared to adapting level, the teacher and student roles are different at the exploring level. Teachers at the exploring level prepare inquiry activities for students, including problem-solving tasks, and act as a guide, not a director, while students are using technology. There was no consistency between having teaching experience and achieving higher levels of TPACK. There were four participants with actual classroom experience; two of them were at the adapting level, and two of them were at the exploring level.

The findings of the present study suggest that investigation of technologies using the technology mapping approach was effective for promoting TPACK development of teachers. The technology mapping approach is different from just presenting a specific technology; it requires establishing connections between content, pedagogy, and affordances and limitations of a particular technology. Previous studies by the developers of this approach also revealed that it was helpful for teachers to combine their knowledge of content, pedagogy, and technology in a meaningful way (Angeli & Valanides, 2009; 2013). Focusing on technical skills and ignoring the relationships between technology, content, and pedagogy is not effective for TPACK development. Teachers should be given opportunities to actively explore and use technologies with a subject-specific perspective (Tondeur et al., 2012).

The last stage of the course was practice, during which participants performed micro-teachings using their third lesson plans. At the end of this stage, after experiencing the implementation of a technology-integrated lesson plan, observing other participants' performances, and receiving feedback from the instructor and the other participants, the participants prepared and submitted their final lesson plans.

When compared to the previous lesson plans, after performing micro-teachings, half of the participants' TPACK levels increased, and the other half of the participants stayed at the same level. Most of the participants were at the exploring level suggesting that T-A-P course design was effectively gaining the required skills to prepare student-centered lesson plans with the effective integration technology for teaching science content. Three participants stayed at the adapting level as they were at the end of the application stage. Two participants reached advancing level, the highest level (Niess et al., 2006) at the end of the course. Teachers at this level can challenge the way the topics are generally taught and prepare open-inquiry activities for students (Niess, 2011). Students are in control of their learning with the help of technology. Teachers at this level prepare technology-based tasks for the development of higher-level thinking and deepening understanding of science concepts (Kaplon-Schilis, 2018; Lyublinskaya &Tournaki, 2014).

The influence of performing micro-teachings for promoting TPACK development of teachers was inconclusive. Half of the participants preserved their previous levels, whereas the other half increased their level of TPACK. Previous research suggests that implementing technology-integrated lesson plans can help teachers assess their own performance, assess their strengths and weaknesses when teaching with technology, and, therefore, promote their TPACK (Baran & Uygun, 2016; Lee & Kim, 2014). Especially micro-teaching lesson study approach was found to be effective for the TPACK development of teachers (Zhang & Tang, 2021). In the present study, the micro-teaching experience was also appreciated by participants and helped some of them to improve their level of TPACK. Micro-teaching is an important element of the course design, and even though its singular influence on TPACK cannot be observed consistently, it is necessary to support the TPACK development of teachers.

When participants' overall development throughout different stages of the course was examined, it was found that the TPACK level of all participants increased at the end of the course at different levels. Most of the participants progressed to two levels of TPACK. There were only two participants who progressed three levels, Birhan and Tomris. Birhan’s initial TPACK level was accepting and at the end of the course, increased to advancing. This might be because she was very eager to learn about the TPACK framework since she was planning to conduct a study about TPACK for her master’s thesis. Tomris started the course at the recognizing level and finished at the exploring level. Even though her initial TPACK was at the lowest level, she was able to reach exploring level. It would be unrealistic to expect all of the participants to achieve the highest level just by attending one graduate course. Improvement of TPACK requires long-term commitment and training.

5.4. Conclusions, Implications, and Recommendations

Theory-Application-Practice course design was created to offer a solution to the problem of identifying effective strategies for the TPACK development of teachers. Findings revealed that the design was effective for graduate science education students' TPACK development. By combining various principles found to be effective for TPACK development in different studies, a course design was proposed and implemented following designed-based research methodology. Based on the findings of this study, the following conclusions can be drawn.

The findings of the present study revealed that science teachers do not graduate with the necessary knowledge and skills for effective technology integration. Consistent with the literature (Agyei & Voogt, 2011; Bate, 2010; Tondeur et al., 2017), the findings of this study revealed that most of the participants' initial TPACK level was very low. Research suggests that only a limited number of beginning teachers can use technology effectively for student-centered teaching (Gao et al., 2011). In the present study, among 12 participants, only one of them used technology to design student-centered tasks in the initial lesson plans. Teacher education has a significant influence on teachers' technology integration practices in their future classrooms (Chai, Koh, & Tsai, 2010; Göktas et al., 2009). In order to raise science teachers with high levels of TPACK, teacher education programs need to be consistent with the underlying characteristics of the TPACK framework and provide effective practices for future teachers.

The T-A-P course design was found to be effective for developing teachers' TPACK. Upon completion of the course based on T-A-P design, all participants increased their level of TPACK. Almost all of the participants' perceived competencies and self-efficacy of TPACK also increased. Participant feedback also suggested that the course design was perceived to be effective by teachers. Therefore, this course design can be informative for teacher educators to guide their efforts.

T-A-P course design was created based on the assumption that teachers already have PCK since participants were graduate students who received a B.S. degree from the elementary science education department. Therefore, it should be adapted according to the needs of pre-service science teachers. Especially the theory stage of this course might need revision before implementing it in undergraduate education since pre-service teachers tend to prefer short lectures combined with practical work (Tondeur et al., 2012). When adapting this course design for pre-service science teachers, the number of articles to be read and discussed can be decreased. Articles providing theoretical information about the TPACK framework can be conserved; however, the research articles can be difficult to read and understand for pre-service science teachers. They can be removed from the reading list. Future research with pre-service teachers is needed to test the effectiveness of course design for pre-service science teachers.

For designing professional development programs and graduate courses, this course design can be helpful. Science teacher education still needs further research about the implementation of alternative professional development programs in different contexts (Baran et al., 2016). The present study aimed to make a contribution by designing an alternative model to be implemented with science teachers. However, much more research was needed to identify the characteristics of effective professional development programs and courses in different contexts with different participants. In addition, not all of the participants of this study were working as a teacher; most of them were graduate students. This might imply an increased motivation to learn about TPACK and, therefore, might have led to improved results. Testing the effectiveness of this design with in-service science teachers is also important.

The development of participants' TPACK was observed at different degrees among participants. Previous research suggests that teachers' personal beliefs as well as the context they are teaching, influence their technology integration practices (Tondeur et al., 2017). Teacher-related variables such as pedagogical beliefs, knowledge, self-efficacy, and experience are important factors affecting technology integration practices (Manfra & Hammond, 2006; Ottenbreit-Leftwich et al., 2018). In the present study, most of the participants graduated from the same university, therefore, received the same undergraduate education, yet, their initial TPACK levels were different.

Working as a teacher also was not related to the development of TPACK levels. Two of the teachers among the participants received the lowest and highest scores for their lesson plans continuously. In addition, when individual scores for self-efficacy and perceived competencies of TPACK were investigated, there was no consistency between participants' scores, their initial levels of TPACK, and the development of TPACK. For example, Nilgün had the highest level of TPACK at the beginning of the course, yet, her self-efficacy and perceived competency scores were lower than most of the other participants. For this reason, future research is needed to investigate the relationships between TPACK development and teacher characteristics as well as to determine how to minimize the negative influences of these factors on teachers' TPACK development.

The most effective part of the course design was found to be the Application stage. This might be explained by participants' lack of technological knowledge at the beginning. In their first interviews, most of the participants mentioned that it was very difficult for them to find technologies to teach science content. After the application stage, they mentioned the importance of learning different technological tools for preparing science teaching lesson plans. Technology knowledge is one of the main components of TPACK. Therefore, if teachers do not possess adequate TK, they cannot improve their TPACK. For this reason, it is important to introduce participants to various technologies that can be used in science education. In addition, the discussion of technologies in terms of educational applications using the technology mapping approach was also found to be helpful by participants and reflected in their latter lesson plans.

The use of technology mapping strategy can also be helpful for improving educational technology courses in undergraduate education (Angeli & Valanides, 2009; 2013); however, future research is necessary to test its effectiveness with pre-service teachers. Technology mapping strategy can be used in the educational technology courses in the department of elementary science education. Rather than giving technology knowledge without any connections to the subject area and subject-specific pedagogies, the technology mapping approach can be useful for pre-service science teachers.

The practice stage, including performing and observing micro-teachings, did not make a significant contribution to participants' TPACK development. Even though participants' found it helpful and some participants' level of TPACK increased after micro-teachings, its effectiveness might be increased with actual classroom experiences. On the other hand, Lale, working as a science teacher at a public elementary school, implemented her third lesson plan in her actual classroom with her students. However, her TPACK level did not change after this implementation either. For this reason, future studies are needed to clarify the influence of actual classroom practices on teachers' TPACK development.

In conclusion, each stage of the course design was appreciated by participants and contributed to their TPACK development. For this reason, the guiding principles used for this design can be recommended to be applied in future studies aiming to improve teachers' TPACK. These principles are:

1. Building a theoretical foundation is important for teachers' TPACK development.
2. Examining examples of technology-integrated learning materials promotes teachers' development of TPACK.
3. Investigation of technologies using the technology mapping approach promotes TPACK development of teachers.
4. Designing technology-enhanced learning materials improves teachers' TPACK.
5. Implementing technology-integrated lesson plans and reflecting on the experiences contribute to the development of TPACK.
6. Providing feedback about teacher designs is important for TPACK development.

In the present study, the course content, activities, and selected technologies were determined for science teaching. However, these principles and the stages of the T-A-

P design are not subject-specific. Future research can benefit from these principles through theory, application, and practice stages in different subject areas by changing the course content.

REFERENCES

Agyei, D., & Voogt, J. (2011). Exploring the potential of the will, skill, tool model in Ghana: Predicting prospective and practicing teachers' use of technology. *Computers & Education, 56*(1), 91–100. https://doi.org/10.1016/j.compedu.2010.08.017

Anderson, T., & Shattuck, J. (2012). Design-based research: A decade of progress in education research? *Educational Researcher, 41*(1), 16–25. https://doi.org/10.3102%2F0013189X11428813

Anderson, T., & Shattuck, J. (2012). Design-based research: A decade of progress in education research? *Educational Researcher*, *41*(1), 16–25. https://doi.org/10.3102%2F0013189X11428813

Angeli, C., & Valanides, N. (2005). Preservice elementary teachers as information and communication technology designers: An instructional systems design model based on an expanded view of pedagogical content knowledge. *Journal of Computer Assisted Learning*, *21*(4), 292-302. https://doi.org/10.1111/j.1365-2729.2005.00135.x

Angeli, C., & Valanides, N. (2009). Epistemological and methodological issues for the conceptualization, development, and assessment of ICT–TPCK: Advances in technological pedagogical content knowledge (TPCK). *Computers & Education*, *52*(1), 154–168. https://doi.org/10.1016/j.compedu.2008.07.006

Angeli, C., & Valanides, N. (2013). Technology mapping: An approach for developing technological pedagogical content knowledge. *Journal of Educational Computing Research*, *48*(2), 199-221. https://doi.org/10.2190%2FEC.48.2.e

Archambault, L. (2016). Exploring the use of qualitative methods to examine TPACK. In Herring, M. C., Koehler, M. J., & Mishra, P. (Eds.) *Handbook of Technological Pedagogical Content Knowledge (TPACK) for Educators: Second Edition* (pp. 65-86). Taylor and Francis Inc. https://doi.org/10.4324/9781315771328

Barab, S., & Squire, K. (2004). Design-based research: Putting a stake in the ground. *Journal of the Learning Sciences*, *13*(1), 1–l4. https://doi.org/10.1207/s15327809jls1301_1

Baran, E., & Canbazoğlu Bilici, S. (2015). Teknolojik pedagojik alan bilgisi (TPAB) üzerine alanyazın incelemesi: Türkiye örneği. *Hacettepe Üniversitesi Eğitim Fakültesi Dergisi (H. U. Journal of Education),* 30(1): 15–32.

Baran, T. E. E., Canbazoğlu-Bilici, S., & Uygun, E. (2016). TPACK-based professional development programs in in-service science teacher education. In Herring, M. C., Koehler, M. J., & Mishra, P. (Eds.) *Handbook of Technological Pedagogical Content Knowledge (TPACK) for Educators: Second Edition* (pp. 281-294). Taylor and Francis Inc. https://doi.org/10.4324/9781315771328

Baran, E., & Uygun, E. (2016). Putting technological, pedagogical, and content knowledge (TPACK) in action: An integrated TPACK-design-based learning (DBL) approach. *Australasian Journal of Educational Technology, 32*(2), 2. https://doi.org/10.14742/ajet.2551

Bate, F. (2010). A bridge too far? Explaining beginning teachers’ use of ICT in Australian schools. *Australasian Journal of Educational Technology, 26*, 1042–1061. https://doi.org/10.14742/ajet.1033

Beck, J. A., & Wynn, H. C. (1998). *Technology in teacher education: Progress along the continuum.* ERIC Document Reproduction No. ED424 212

Bell, R. L., Maeng, J. L., & Binns, I. C. (2013). Learning in context: Technology integration in a teacher preparation program informed by situated learning theory. *Journal of Research in Science Teaching, 50*(3), 348-379. https://doi.org/10.1002/tea.21075

Bell, R. L., & Trundle, K. C. (2008). The use of a computer simulation to promote scientific conceptions of moon phases. *Journal of Research in Science Teaching*, *45*(3), 346-372. https://doi.org/10.1002/tea.20227

Boschman, F., McKenney, S., Pieters, J., & Voogt, J. (2016). Exploring the role of content knowledge in teacher design conversations. *Journal of Computer Assisted Learning*, *32*(2), 157–169. https://doi.org/10.1111/jcal.12124

Bowen, G. A. (2009). Supporting a grounded theory with an audit trail: an illustration. *International Journal of Social Research Methodology*, *12*(4), 305–316. https://doi.org/10.1080/13645570802156196

Brantley-Dias, L. & Ertmer, P. A. (2013). Goldilocks and TPACK. *Journal of Research on Technology in Education, 46*(2), 103-128. https://doi.org/10.1080/15391523.2013.10782615

Brown, A. L. (1992). Design experiments: Theoretical and methodological challenges in creating complex interventions in classroom settings. *The Journal of the Learning Sciences, 2*(2), 141–178. https://doi.org/10.1207/s15327809jls0202_2

Canbazoğlu-Bilici, S., Yamak, H., Kavak, N., & Guzey, S. S. (2013). Technological Pedagogical Content Knowledge Self-Efficacy Scale (TPACK-SeS) for pre-service science teachers: Construction, validation, and reliability. *Eurasian Journal of Educational Research, 52*, 37-60.

Chai, C. S., & Koh, J. H. L. (2017). Changing teachers' TPACK and design beliefs through the Scaffolded TPACK Lesson Design Model (STLDM). *Learning: research and Practice*, 3(2), 114-129. https://doi.org/10.1080/23735082.2017.1360506

Chai, C. S., Koh, J. H. L., & Tsai, C. C. (2010). Facilitating preservice teachers' development of technological, pedagogical, and content knowledge (TPACK). *Journal of Educational Technology & Society, 13*(4), 63-73.

Chai, C. S., Koh, J. H. L., & Tsai, C. C. (2016). A review of the quantitative measures of technological pedagogical content knowledge (TPACK). In Herring, M. C., Koehler, M. J., & Mishra, P. (Eds.) *Handbook of Technological Pedagogical Content Knowledge (TPACK) for Educators: Second Edition* (pp. 87-106). Taylor and Francis Inc. https://doi.org/10.4324/9781315771328

Chai, C. S., Koh, J.H.L., Tsai, C. C., & Tan, L.L.W. (2011). Modeling primary school preservice teachers' technological pedagogical content knowledge (TPACK) for meaningful learning with information and communication technology (ICT). *Computers & Education*, *57*(1), 1184–1193. https://doi.org/10.1016/j.compedu.2011.01.007

Christensen, K. D. N. & West, R. E. (2018). The development of design-based research. In R. E. West, *Foundations of learning and instructional design technology: The past, present, and future of learning and instructional design technology*. EdTech Books. https://edtechbooks.org/lidtfoundations/development_of_design-based_research

Cobb, P., Confrey, J., diSessa, A., Lehrer, R., & Schauble, L. (2003). Design experiments in educational research. *Educational Researcher*, *32*(1), 9–13. https://doi.org/10.3102%2F0013189X032001009

Collins, A. (1992). Toward a design science of education. In E. Scanlon & T. O'Shea (Eds.), *New directions in educational technology*. Springer. https://doi.org/10.1007/978-3-642-77750-9_2

Collins, A., Joseph, D., & Bielaczyc, K. (2004). Design research: Theoretical and methodological issues. *The Journal of the Learning Sciences*, *13*(1), 15–42. https://doi.org/10.1207/s15327809jls1301_2

Cox, S. & Graham, C. R. (2009). Diagramming TPACK in practice: Using an elaborated model of the TPACK Framework to analyze and depict teacher knowledge. *Tech Trends 53*(5), 60-69. https://doi.org/10.1007/s11528-009-0327-1

Danday, B. A. (2019). Active vs. passive microteaching lesson study: Effects on pre-service teachers' technological pedagogical content knowledge International *Journal of Learning, Teaching and Educational Research, 18*(6), 181-200. https://doi.org/10.26803/ijlter.18.6.11

De Vet, E., Brug, J., De Nooijer, J., Dijkstra, A., & De Vries, N. K. (2005). Determinants of forward stage transitions: a Delphi study. *Health Education Research*, *20*(2), 195-205. https://doi.org/10.1093/her/cyg111

Design-Based Research Collective. (2003). Design-based research: An emerging paradigm for educational inquiry. *Educational Researcher*, *32*(1), 5–8. https://doi.org/10.3102%2F0013189X032001005

Ersoy, M., Kabakçı Yurdakul, I., & Ceylan, B. (2016). Investigating preservice teachers' TPACK competencies through the lenses of ICT skills: An experimental study. Education and Science, 41, 119–135. https://doi.org/10.15390/EB.2016.6345

Farjon, D., Smits, A., & Voogt, J. (2019). Technology integration of pre-service teachers explained by attitudes and beliefs, competency, access, and experience. *Computers & Education*, *130*, 81-93. https://doi.org/10.1016/j.compedu.2018.11.010

Fisser, P., Voogt, J., van Braak, J., & Tondeur, J. (2015). Measuring and assessing tpack (technological pedagogical content knowledge). In J. Spector (Ed.), *The SAGE encyclopedia of educational technology* (pp. 490-492). SAGE Publications, Inc., https://dx.doi.org/10.4135/9781483346397.n205

Fraenkel, J. R., Wallen, N. E., & Hyun, H. H. (2012). *How to design and evaluate research in education* (8th ed.). McGraw-Hill.

Figg, C., & Jaipal-Jamani, K. (2013). Using TPACK-in-Practice workshops to enable teacher candidates to create professional development workshops that develop tech-enhanced teaching. In R. McBride & M. Searson (Eds.), *Proceedings of Society for Information Technology & Teacher Education international conference* (pp. 5040-5047). Association for the Advancement of Computing in Education (AACE).

Figg, C., & Jaipal-Jamani, K. J. (2014). Transforming classroom practice: Technology professional development that works!. *Teaching & Learning*, *8*(1), 87–98. https://doi.org/10.26522/tl.v8i1.431

Goldenberg, P. (2000). *Thinking (and talking) about technology in math classrooms*. The K–12 Mathematics Curriculum Center. http://mcc.edc.org/pdf/iss_tech.pdf

Graham, C. R. (2011). Theoretical considerations for understanding technological pedagogical content knowledge (TPACK). *Computers & Education*, *57*(3), 1953-1960. https://doi.org/10.1016/j.compedu.2011.04.010

Graham, C. R., Borup, J., & Smith, N. B. (2012). Using TPACK as a framework to understand teacher candidates’ technology integration decisions. *Journal of Computer Assisted Learning*, *28*(6), 530–546. https://doi.org/10.1111/j.1365-2729.2011.00472.x

Graham, R. C., Burgoyne, N., Cantrell, P., Smith, L., St Clair, L., & Harris, R. (2009). TPACK development in science teaching: Measuring the TPACK confidence of inservice science teachers. *TechTrends*, *53*(5), 70–79. https://doi.org/10.1007/s11528-009-0328-0

Gravemeijer, K., & Cobb, P. (2006). Design research from a learning design perspective. In J. van der Akker, K. Gravemeijer, S. McKenney, & N. Nieveen (Eds.), *Educational Design Research* (pp. 17-51). Routledge.

Grimalt-Álvaro, C., Ametller, J., & Pintó, R. (2019). Factors shaping the uptake of ICT in science classrooms: A study of a large-scale introduction of interactive whiteboards and computers. *International Journal of Innovation in Science and Mathematics Education*, *27*(1), 18-36. https://doi.org/10.30722/IJISME.27.01.002

Guzey, S. S., & Roehrig, G. H. (2009). Teaching science with technology: Case studies of science teachers' development of technology, pedagogy, and content knowledge. *Contemporary Issues in Technology and Teacher Education, 9*(1), 25-45.

Harris, J. B., Hofer, M. J., Blanchard, M. R., Grandgenett, N. F., Schmidt, D. A., van Olphen, M., & Young, C. A. (2010). "Grounded" technology integration: Instructional planning using curriculum based activity type taxonomies. *Journal of Technology and Teacher Education, 18*(4), 573–605.

Herrington, J., McKenney, S., Reeves, T., & Oliver, R. (2007). Design-based research and doctoral students: Guidelines for preparing a dissertation proposal. In C. Montgomerie & J. Seale (Eds.), *Proceedings of EdMedia 2007: World Conference on Educational Multimedia, Hypermedia & Telecommunications* (pp. 4089-4097). AACE. https://ro.uow.edu.au/edupapers/627/

Hofer, M., & Harris, J. (2010). Differentiating TPACK development: Using learning activity types with in-service and pre-service teachers. In C. D. Maddux, D. Gibson, & B. Dodge (Eds.) *Research highlights in technology and teacher education* (pp. 295–302). Society for Information Technology and Teacher Education.

Hsu, C. C., & Sandford, B. A. (2007). The Delphi technique: Making sense of consensus. *Practical Assessment, Research & Evaluation*, *12*(10), 1–8. https://doi.org/10.7275/pdz9-th90

Hsu, C. Y., Liang, J. C., Chai, C. S., & Tsai, C. C. (2013). Exploring preschool teachers' technological pedagogical content knowledge of educational games. *Journal of Educational Computing Research*, *49*(4), 461–479. https://doi.org/10.2190%2FEC.49.4.c

Hsu, Y. S., Yeh, Y. F., & Wu, H. K. (2015). The TPACK-P framework for science teachers in a practical teaching context. In Hsu, Y. S. (Ed.) *Development of Science Teachers' TPACK.* Springer. https://doi.org/10.1007/978-981-287-441-2_2

Jaipal, K., & Figg, C. (2010). Unpacking the "Total PACKage": Emergent TPACK characteristics from a study of pre-service teachers teaching with technology. *Journal of Technology and Teacher Education, 18*(3), 415–441.

Jaipal-Jamani, K., & Figg, C. (2015). A case study of a TPACK-based approach to teacher professional development: Teaching science with blogs. *Contemporary issues in technology and teacher education*, *15*(2), 161-200.

Jang, S. J. (2010). Integrating the interactive whiteboard and peer coaching to develop the TPACK of secondary science teachers. *Computers & Education, 55*(4), 1744-1751. https://doi.org/10.1016/j.compedu.2010.07.020

Jang, S. J., & Chen, K. C. (2010). From PCK to TPACK: Developing a transformative model for pre-service science teachers. *Journal of Science Education and Technology*, *19*(6), 553-564. https://doi.org/10.1007/s10956-010-9222-y

Jang, S. J., & Tsai, M. F. (2013). Exploring the TPACK of Taiwanese secondary school science teachers using a new contextualized TPACK model. *Australasian Journal of Educational Technology*, *29*(4), 566–580. https://doi.org/10.14742/ajet.282

Jimoyiannis, A. (2008). Factors determining teachers' beliefs and perceptions of ICT in education. In A. Cartelli, & M. Palma (Eds.), *Encyclopedia of information communication technology* (pp. 321–334). IGI Global. https://doi.org/10.4018/978-1-59904-845-1

Jimoyiannis, A. (2010). Designing and implementing an integrated technological pedagogical science knowledge framework for science teachers professional development. *Computers & Education,* *55*(3), 1259-1269. https://doi.org/10.1016/j.compedu.2010.05.022

Joseph, D. (2004). The practice of design-based research: Uncovering the interplay between design, research, and the real-world context. *Educational Psychologist, 39*(4), 235–242. https://doi.org/10.1207/s15326985ep3904_5

Joyce, B. R., & Showers, B. (1995). *Student achievement through staff development: Fundamentals of school renewal* (2nd ed.). Longman.

Kabakci Yurdakul, I., Odabasi, H. F., Kilicer, K., Coklar, A. N., Birinci, G., & Kurt, A. A. (2012). The development, validity and reliability of TPACK-deep: A technological pedagogical content knowledge scale. *Computers & Education, 58*(3), 964-977. https://doi.org/10.1016/j.compedu.2011.10.012

Kapici, H. O., & Akcay, H. (2020). Improving student teachers' TPACK self-efficacy through lesson planning practice in the virtual platform. *Educational Studies*, 1-23. https://doi.org/10.1080/03055698.2020.1835610

Kaplon-Schilis, A. (2018). Development and transfer of technological pedagogical content knowledge (TPACK) of special education teachers [Doctoral dissertation, The City University of New York]. CUNY Academic Works. https://academicworks.cuny.edu/gc_etds/2835

Kaplon-Schilis, A. & Lyublinskaya, I. (2020). Analysis of relationship between five domains of TPACK framework: TK, PK, CK Math, CK Science, and TPACK of pre-service special education teachers. *Technology, Knowledge and Learning, 25*, 25–43. https://doi.org/10.1007/s10758-019-09404-x

Kaya, S., & Dağ, F. (2013). Turkish adaptation of technological pedagogical content knowledge survey for elementary teachers. *Educational Sciences: Theory and Practice, 13*(1), 302–306.

Keengwe, J., & Onchwari, G. (2011). Fostering meaningful student learning through constructivist pedagogy and technology integration. *International Journal of Information and Communication Technology Education (IJICTE), 7*(4), 1-10. http://doi.org/10.4018/jicte.2011100101

Kinuthia, W., Brantley-Dias, L., & Clarke, P.A.J. (2010). Development of pedagogical technology integration content knowledge in preparing mathematics pre-service teachers: The role of instructional case analyses and reflection. *Journal of Technology and Teacher Education, 18*(4), 645–669.

Koehler, M. J., & Mishra, P. (2005). What happens when teachers design educational technology? The development of technological pedagogical content knowledge. *Journal of Educational Computing Research, 32*(2), 131-152. https://doi.org/10.2190%2F0EW7-01WB-BKHL-QDYV

Koehler, M. J., & Mishra, P. (2009). What is technological pedagogical content knowledge? *Contemporary Issues in Technology and Teacher Education, 9*(1), 60-70.

Koehler, M. J., Mishra, P., & Cain, W. (2013). What is technological pedagogical content knowledge (TPACK)? *Journal of Education, 193*(3), 13-20. https://doi.org/10.1177%2F002205741319300303

Koehler, M. J., Mishra, P., Hershey, K., & Peruski, L. (2004). With a little help from your students: A new model for faculty development and online course design. *Journal of Technology and Teacher Education*, *12*(1), 25-55.

Koehler, M., Mishra, P., Kereluik, K., Shin, T., & Graham, C. (2014). The technological pedagogical content knowledge framework. In J. M. Spector, M. D. Merrill, J. Elen, & M. J. Bishop (Eds.), *Handbook of research on educational communications and technology* (pp. 101–111). Springer Science+Business Media. https://doi.org/10.1007/978-1-4614-3185-5_9

Koh, J. H. L., & Chai, C. S. (2014). Teacher clusters and their perceptions of technological pedagogical content knowledge (TPACK) development through ICT lesson design. *Computers & Education*, *70*, 222-232. https://doi.org/10.1016/j.compedu.2013.08.017

Koh, J. H. L., Chai, C. S., & Lim, W. Y. (2017). Teacher professional development for TPACK-21CL: Effects on teacher ICT integration and student outcomes. *Journal of Educational Computing Research*, *55*(2), 172-196. https://doi.org/10.1177%2F0735633116656848

Koh, J. H. L., Chai, C. S., & Tay, L. Y. (2014). TPACK-in-Action: Unpacking the contextual influences of teachers’ construction of technological pedagogical content knowledge (TPACK). *Computers in Education, 78*, 20–29. https://doi.org/10.1016/j.compedu.2014.04.022

Koh, J.H.L., Chai, C. S., & Tsai, C. C. (2010). Examining the technological pedagogical content knowledge of Singapore preservice teachers with a large-scale survey. *Journal of Computer Assisted Learning*, *26*(6), 563–573. https://doi.org/10.1111/j.1365-2729.2010.00372.x

Koh, J. H., & Divaharan, S. (2011). Developing pre-service teachers' technology integration expertise through the TPACK-developing instructional model. *Journal of Educational Computing Research*, *44*(1), 35-58. https://doi.org/10.2190%2FEC.44.1.c

Kramarski, B., & Michalsky, T. (2010). Preparing preservice teachers for self-regulated learning in the context of technological pedagogical content knowledge. *Learning and Instruction, 20*(5), 434–447. https://psycnet.apa.org/doi/10.1016/j.learninstruc.2009.05.003

Lee, Y., & Lee, J. (2014). Enhancing pre-service teachers' self-efficacy beliefs for technology integration through lesson planning practice. *Computers & Education*, *73*, 121-128. https://doi.org/10.1016/j.compedu.2014.01.001

Lee, M. H., Linn, M. C., Varma, K., & Liu, O. L. (2010). How do technology-enhanced inquiry science units impact classroom learning? *Journal of Research in Science Teaching*, *47*, 71–90. https://doi.org/10.1002/tea.20304

Lee, C. J., & Kim, C. (2014). An implementation study of a TPACK-based instructional design model in a technology integration course. *Educational Technology Research and Development*, *62*(4), 437-460. https://doi.org/10.1007/s11423-014-9335-8

Lee, M. H., & Tsai, C.C. (2010). Exploring teachers' perceived self efficacy and technological pedagogical content knowledge with respect to educational use of the World Wide Web. *Instructional Science*, *38*(1), 1–21. https://doi.org/10.1007/s11251-008-9075-4

Lin, T. C., Tsai, C. C., Chai, C. S., & Lee, M. H. (2013). Identifying science teachers' perceptions of technological pedagogical and content knowledge (TPACK). *Journal of Science Education and Technology*, *22*, 325-336. https://doi.org/10.1007/s10956-012-9396-6

Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic inquiry*. SAGE.

Lincoln, Y.S. & Guba, E. G. (1986). But is it rigorous? Trustworthiness and authenticity in naturalistic evaluation. *New Directions for Program Evaluation*, *1986*, 73-84. https://doi.org/10.1002/ev.1427

Linstone, H. A., & Turoff, M. (1975). The Delphi method: Techniques and applications. Addison-Wesley.

Lyublinskaya, I., & Tournaki, N. (2011). The effect of teaching and learning with Texas Instruments handheld devices on student achievement in algebra. *Journal of Computers in Mathematics and Science Teaching*, *30*(1), 5-35.

Lyublinskaya, I. & Tournaki, N. (2012) The effects of teacher content authoring on TPACK and on student achievement in algebra: Research on instruction with the TI-Nspire handheld. In R. Ronau, C. Rakes, & M. Niess (Eds.), *Educational technology, teacher knowledge, and classroom impact: A research handbook on frameworks and approaches* (pp. 295-322). IGI Global. https://doi.org/10.4018/978-1-60960-750-0.ch013

Lyublinskaya, I. & Tournaki, N. (2013). Integrating TPACK Framework into Coursework and its Effect on Changes in TPACK of Pre-Service Special Education Teachers. In R. McBride & M. Searson (Eds.), *Proceedings of Society for Information Technology & Teacher Education International Conference 2013* (pp. 5006-5011). Association for the Advancement of Computing in Education (AACE).

Lyublinskaya, I. & Tournaki, N. (2014). Preparing special education teachers for teaching mathematics and science with technology by integrating the TPACK framework into the curriculum: A study of teachers' TPACK development through assessment of lesson plans. *Journal of Technology and Teacher Education*, *22*(4), 449-470.

McCandliss, B. D., Kalchman, M., & Bryant, P. (2003). Design experiments and laboratory approaches to learning: Steps toward collaborative exchange. *Educational Researcher*, *32*(1), 14–16. https://doi.org/10.3102%2F0013189X032001014

McCrory, R. (2008). Science, technology, and teaching: The topic-specific challenges of TPCK in science. In AACTE Committee on Innovation and Technology (Ed.), *Handbook of Technological Pedagogical Content Knowledge (TPCK) for Educators* (pp. 193-206). Routledge. https://doi.org/10.4324/9781315759630

Merriam, S. B. (2009). *Qualitative Research: A Guide to Design and Implementation.* Jossey-Bass.

Mishra, P. (2019). Considering contextual knowledge: The TPACK diagram gets an upgrade, *Journal of Digital Learning in Teacher Education*, *35*(2), 76-78. https://doi.org/10.1080/21532974.2019.1588611

Mishra, P., & Koehler, M. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *The Teachers College Record*, *108*(6), 1017-1054. https://doi.org/10.1111%2Fj.1467-9620.2006.00684.x

Mishra, P., Peruski, L., & Koehler, M. (2007). Developing technological pedagogical content knowledge (TPCK) through teaching online. In R. Carlsen et al. (Eds.), *Proceedings of Society for Information Technology & Teacher Education International Conference 2007* (pp. 2208–2213). Association for the Advancement of Computing in Education (AACE).

Mouza, C. (2016). Developing and assessing TPACK among pre-service teachers: A synthesis of research. In Herring, M. C., Koehler, M. J. , & Mishra, P. (Eds.) *Handbook of Technological Pedagogical Content Knowledge (TPACK) for Educators: Second Edition* (pp. 169-190). Taylor and Francis Inc. https://doi.org/10.4324/9781315771328

Mouza, C., Karchmer-Klein, R., Nandakumar, R., Yilmaz Ozden, S., & Hu, L. (2014). Investigating the impact of an integrated approach to the development of preservice teachers' technological pedagogical content knowledge (TPACK). *Computers & Education*, *71*, 206–221. https://doi.org/10.1016/j.compedu.2013.09.020

Niess, M. L. (2005). Preparing teachers to teach science and mathematics with technology: developing a technology pedagogical content knowledge. *Teaching and Teacher Education*, *21*(5), 509–523. https://doi.org/10.1016/j.tate.2005.03.006

Niess, M. L. (2008). Guiding preservice teachers developing TPCK. In AACTE Committee on Innovation and Technology (Ed.), *Handbook of Technological Pedagogical Content Knowledge (TPCK) for Educators* (pp. 223-250). Routledge. https://doi.org/10.4324/9781315759630

Niess, M. L. (2011). Investigating TPACK: Knowledge growth in teaching with technology. *Journal of Educational Computing Research*, *44*(3), 299-317. https://doi.org/10.2190%2FEC.44.3.c

Niess, M. L. (2012). Teacher knowledge for teaching with technology: A TPACK lens. In C.R. Rakes, R.N. Ronau, & M.L. Niess (Eds.), Educational technology, teacher knowledge, and classroom impact: A research handbook on frameworks and approaches (pp. 1-15). IGI Global.

Niess, M. L. (2013). Central component descriptors for levels of technological pedagogical content knowledge. *Journal of Educational Computing Research*, *48*(2), 173-198. https://doi.org/10.2190%2FEC.48.2.d

Niess, M. L., Suharwoto, G., Lee, K., & Sadri, P. (2006, April). Guiding inservice mathematics teachers in developing TPCK [Conference presentation]. American Education Research Association (AERA)Annual Conference, San Francisco, CA, United States.

Ottenbreit-Leftwich, A. T., Glazewski, K. D., Newby, T. J., & Ertmer, P. A. (2010). Teacher value beliefs associated with using technology: Addressing professional and student needs. *Computers & education*, *55*(3), 1321-1335. https://doi.org/10.1016/j.compedu.2010.06.002

Pierson, M. E. (2001). Technology integration practice as a function of pedagogical expertise. *Journal of research on computing in education*, *33*(4), 413-430. https://doi.org/10.1080/08886504.2001.10782325

Roussinos, D. & Jimoyiannis, A. (2019). Examining primary education teachers' perceptions of TPACK and the related educational context factors. *Journal of Research on Technology in Education*, *51*(4), 377-397. https://doi.org/10.1080/15391523.2019.1666323

Sarkar, S. (2012). The role of ICT in higher education for the 21st century. *The Science Probe*, *1*(1), 30-41.

Schmid, M., Brianza, E., & Petko, D. (2020). Developing a short assessment instrument for Technological Pedagogical Content Knowledge (TPACK. xs) and comparing the factor structure of an integrative and a transformative model. *Computers & Education*, *157*, 103967. https://doi.org/10.1016/j.compedu.2020.103967

Schmidt, D. A., Baran, E., Thompson, A. D., Mishra, P., Koehler, M. J., & Shin, T. S. (2009). Technological pedagogical content knowledge (TPACK) the development and validation of an assessment instrument for preservice teachers. *Journal of Research on Technology in Education*, *42*(2), 123–149. https://doi.org/10.1080/15391523.2009.10782544

Schnittka, C., & Bell, R. (2009). Preservice biology teachers' use of interactive display systems to support reforms-based science instruction. *Contemporary Issues in Technology and Teacher Education*, *9*(2), 131-159.

Scott, E. E., Wenderoth, M. P., & Doherty, J. H. (2020). Design-based research: A methodology to extend and enrich biology education research. *CBE—Life Sciences Education*, *19*(3), 1-20. https://doi.org/10.1187/cbe.19-11-0245

Shulman, L. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, *15*(2), 4–14. https://doi.org/10.3102%2F0013189X015002004

Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review*, *57*(1), 1–22. https://doi.org/10.17763/haer.57.1.j463w79r56455411

Shavelson, R. J., Phillips, D. C., Towne, L., & Feuer, M. J. (2003). On the science of education design studies. *Educational Researcher*, *32*(1), 25–28. https://doi.org/10.3102%2F0013189X032001025

Stover, S. & Veres, M. (2013). TPACK in higher education: Using the framework for professional development. *Global Education Journal*, *1*, 93-110.

Thompson, A. D., & Mishra, P. (2007). Breaking news: TPCK becomes TPACK! *Journal of Computing in Teacher Education*, *24*(2), 38–64. https://doi.org/10.1080/10402454.2007.10784583

Tondeur, J., Pareja Roblin, N., van Braak, J., Voogt, J., & Prestridge, S. (2017). Preparing beginning teachers for technology integration in education: Ready for take-off?. *Technology, Pedagogy and Education*, *26*(2), 157-177. https://doi.org/10.1080/1475939X.2016.1193556

Tondeur, J., Scherer, R., Siddiq, F., & Baran, E. (2020). Enhancing pre-service teachers' technological pedagogical content knowledge (TPACK): A mixed-method study. *Education Tech. Research Dev. 68*, 319–343. https://doi.org/10.1007/s11423-019-09692-1

Tondeur, J., Van Braak, J., Sang, G., Voogt, J., Fisser, P., & Ottenbreit-Leftwich, A. (2012). Preparing pre-service teachers to integrate technology in education: A synthesis of qualitative evidence. *Computers & Education*, *59*(1), 134-144. https://doi.org/10.1016/j.compedu.2011.10.009

Trowbridge, L. W., Bybee, R. W., & Powell, J. C. (2008). *Teaching secondary school science: Strategies for developing scientific literacy* (9th ed.). Pearson/Merrill/Prentice Hall.

Valanides, N. (2018). Technological tools: From technical affordances to educational affordances. *Problems of Education in the 21st Century*, *76*(2), 116-120. http://oaji.net/articles/2017/457-1524597237.pdf

van der Akker, J. Gravemeijer, K., McKenney, S. & Nieveen, N. (2006) Introducing educational research design. In J. van der Akker, K. Gravemeijer, S. McKenney, & N. Nieveen, (Eds.), *Educational Design Research* (pp. 1-8). Routledge. https://doi.org/10.4324/9780203088364

Varma, K., Husic, F., & Linn, M. C. (2008). Targeted support for using technology-enhanced science inquiry models. *Journal of Science Education and Technology*, *17*, 341–356. https://doi.org/10.1007/s10956-008-9104-8

Voithofer, R., & Nelson, M. J. (2021). Teacher educator technology integration preparation practices around TPACK in the United States. *Journal of teacher education*, *72*(3), 314-328. https://doi.org/10.1177/0022487120949842

Voogt, J., Fisser, P., Pareja Roblin, N., Tondeur, J., & van Braak, J. (2013). Technological pedagogical content knowledge–a review of the literature. *Journal of computer assisted learning*, *29*(2), 109-121. https://doi.org/10.1111/j.1365-2729.2012.00487.x

Voogt, J., Fisser, P., Tondeur, J., & van Braak, J. (2016). Using theoretical perspectives in developing an understanding of TPACK. In Herring, M. C., Koehler, M. J. , & Mishra, P. (Eds.) *Handbook of Technological Pedagogical Content Knowledge (TPACK) for Educators: Second Edition* (pp. 33-52). Taylor and Francis Inc. https://doi.org/10.4324/9781315771328

Voogt, J., Laferri`ere, T., Breuleux, A., Itow, R. C., Hickey, D. T., & McKenney, S. (2015). Collaborative design as a form of professional development. *Instructional Science*, *43*(2), 259–282. https://doi.org/10.1007/s11251-014-9340-7

Wallace, R. M. (2004). A framework for understanding teaching with the internet. *American Educational Research Journal*, *41*(2), 447–488. https://doi.org/10.3102%2F00028312041002447

Wang, F., & Hannafin, M. J. (2005). Design-based research and technology-enhanced learning environments. *Educational Technology Research and Development (ETR&D)*, *53*(4), 5–23. https://doi.org/10.1007/BF02504682

Wang, J., Odell, S. J., & Schwille, S. A. (2008). Effects of teacher induction on beginning teachers' teaching: A critical review of the literature. *Journal of teacher education*, *59*(2), 132-152. https://doi.org/10.1177%2F0022487107314002

Wang, Q., & Zhao, G. (2021). ICT self-efficacy mediates most effects of university ICT support on preservice teachers' TPACK: Evidence from three normal universities in China. B*ritish Journal of Educational Technology*, *52*(6), 2319-2339. https://doi.org/10.1111/bjet.13141

Wu, H. K., & Huang, Y.L. (2007). Ninth-grade student engagement in teacher-centered and student-centered technology-enhanced learning environments. *Science Education*, *91*, 727–749. https://doi.org/10.1002/sce.20216

Yeh, Y. F., Chan, K. K. H., & Hsu, Y. S. (2021). Toward a framework that connects individual TPACK and collective TPACK: A systematic review of TPACK studies investigating teacher collaborative discourse in the learning by design process. *Computers & Education*, *171*, 104238. https://doi.org/10.1016/j.compedu.2021.104238

Yeh, Y. F., Hsu, Y. S., Wu, H. K., Hwang, F. K., & Lin, T. C. (2014). Developing and validating technological pedagogical content knowledge-practical (TPACK-practical) through the Delphi survey technique. *British Journal of Educational Technology*, *45*(4), 707–722. https://doi.org/10.1111/bjet.12078

Yerdelen-Damar, S., Boz, Y., & Aydın-Günbatar, S. (2017). Mediated effects of technology competencies and experiences on relations among attitudes towards technology use, technology ownership, and self efficacy about technological pedagogical content knowledge. *Journal of Science Education and Technology*, *26*(4), 394-405. https://doi.org/10.1007/s10956-017-9687-z

Zhang, W., & Tang, J. (2021). Teachers' TPACK development: A review of literature. *Open Journal of Social Sciences*, *9*(7), 367-380. https://doi.org/10.4236/jss.2021.97027

Zinger, D., Naranjo, A., Naranjo A., Gilbertson, N., & Warschauer, M. (2017). A design-based research approach to improving professional development and teacher knowledge: The case of the Smithsonian Learning Lab. *Contemporary Issues in Technology and Teacher Education, 17*(3), 388-410.

APPENDICES

A. TEACHING SCIENCE WITH TECHNOLOGY COURSE SYLLABUS

Course Description:

This course is designed to provide students opportunities to learn about the current state of theory and research on technology integration into science education. There will be a review of the Technological Pedagogical Content Knowledge (TPACK) framework and TPACK research in science education/science teacher education; demonstration and investigation of technologies for improving science teaching; examination of technology integrated science lesson examples, and development and implementation of technology integrated science lessons.

The main methods by means of which the course is to be conducted are through:

- The presentations and discussions of articles and/or texts assigned,
- Online forum discussions out of the classroom,
- In-class activities related to technology integration into science education,
- Development and implementation of lesson plans,
- Reflecting upon classroom practices and weekly readings,
- Reviewing and critiquing others' work.

Course Objectives:

1. To analyze the TPACK framework and its implications for science education;
2. To discuss the importance, advantages, and disadvantages of technology integration into science education;
3. To develop an awareness related to the characteristics of educational technologies that can be used to improve the quality of science teaching and learning;
4. To examine various technologies that can be used in science education;
5. To engage in technology integrated lessons throughout the course;

6. To examine and reflect upon technology integrated science lesson examples;
7. To experience the technology integration process while preparing lesson plans and activities for teaching science;
8. To design a unit of instruction for a science topic using the TPACK framework;
9. To develop technological skills to be able to combine technology and pedagogy effectively for teaching science content;
10. To develop an interest in research on technology integration into science education.

Reading Materials:

Each week you will be assigned specific readings according to the topic of that week's discussion. There is no single textbook that is going to be followed. However, the following books are very helpful if you are interested in further readings.

- AACTE Committee on Innovation and Technology (Ed.). (2008). *The handbook of technological pedagogical content knowledge (TPCK) for educators*. Mahwah, NJ: Lawrence Erlbaum Associates.
- Keengwe, J. (Ed.). (2013). *Research perspectives and best practices in educational technology* integration. Hershey, PA: Information Science Reference.
- Tomei, L. A. (Ed.). (2013). *Learning tools and teaching approaches through ICT advancements.* Hershey, PA: Information Science Reference.

Online Platforms:

- METU-Class: Throughout the semester, we will use METU-Class for online activities such as forum discussions, assignments, file uploads, announcements and so on. Please complete your profile information and follow the updates.
- Facebook group: We will have a Facebook group for small talks, chat, and any questions related to the course and/or activities. It will make it easier for all of us to communicate simultaneously. Please join the group and turn on notifications. Do not hesitate to share anything that is related to our course.

Attendance and participation:

This is a participatory class which means your attendance and engagement in activities are essential for an effective learning environment. You are expected to keep up with your readings regularly, complete your assignments and participate in the classroom/online discussions and activities. If you have an important excuse for not participating/arriving late/leaving early to a class, please inform the course assistant beforehand.

Academic Ethics and Plagiarism:

All assignments you submit should be the result of your own effort. Any form of academic dishonesty (e.g., cheating, plagiarism) will not be tolerated and will result in failure of the course and/or formal disciplinary proceedings. Plagiarism is a specific form of cheating. It means "using, presenting or submission of someone else's ideas or phrasing without clearly acknowledging the source of that information (that is without any citation or credits) and representing those ideas or phrasing as our own, either on purpose or through carelessness". For more information about plagiarism, go to the webpage: http://fbe.metu.edu.tr/plagiarism.

Give the full reference of any source you used for your work. Please use APA (6th edition - https://owl.english.purdue.edu/owl/resource/560/01/) style for citation of sources.

Assignments and Grading:

1. ***<u>Weekly readings and reflections (%10):</u>*** Each week, you will be assigned readings. We will have an online forum on METU-class for each week's readings. Before the class, you are expected to reflect upon that weeks' readings by (1) sharing the main points you have drawn from the texts; (2) preparing at least two questions for classroom discussions; and (3) discussing how this new information can be related to real science classroom settings. You need to share your reflections on METU-Class until 23:59 on Sunday before the class. You are also encouraged to read each other's reflections and share your ideas.

2. ***Lesson plans (%10 * 4 = %40):*** Within the semester, you will be asked to prepare four lesson plans according to the format given to you. In these lesson plans, you are asked to plan to teach a science topic by choosing the right pedagogy and technology. You will also share your lesson plans with each other on METU-Class until the class hours of the assigned week. You are expected to provide feedback on at least two of your friends' lesson plans.
3. ***Interviews (%10):*** In order to provide you the opportunity to elaborate your ideas on your lesson plans, an interview will be conducted with you after your submission of each lesson plan. Each interview will take approximately 15-20 minutes and can be conducted face-to-face or online, according to your time schedule.
4. ***Group presentation and report (%10):*** Within the semester, you will be asked to make a group presentation about a technological tool (not included in the syllabus – please contact the course assistant before you decide) that can be used in science teaching. You will make a demonstration in the class and prepare a presentation report including your ideas about (1) why you chose that specific tool; (2) how that tool can improve science instruction; (3) which teaching methods and science topics can be combined with that tool. You are expected to submit your report to METU-Class until the following Friday, 23:59.
5. ***Micro-teaching and presentation report (%10):*** At the end of the semester, you will perform a micro-teaching by presenting your third lesson plan in the classroom. You will also be asked to write a reflection and submit it to METU-Class about your teaching until the following Friday, 23:59.
6. ***Feedback (%5):*** After each lesson, you are expected to provide feedback on that day's lesson and each other's work by sharing your ideas about (1) what can be done to improve the quality of instruction/discussion/presentation/lesson plan etc. and (2) what was the most effective part of the instruction/discussion/presentation/lesson plan etc. You are expected to submit your feedback to METU-Class until the following Friday, 23:59.

7. ***Article/News/Activity search (%5):*** Before each classroom meeting, you need to find at least one article/news/activity (or something else that you think is important to share with all of us) related to the topic of that week and share it on the course's Facebook page.
8. ***Participation (%10):*** Since the quality of the classroom activities depends on your active participation, you are expected to (1) arrive on time and stay until the end of each meeting; (2) complete the assignments on time; (3) participate actively in classroom discussions and activities. When you have an important excuse for missing a class, please inform the course assistant beforehand.

COURSE SCHEDULE			
	Topic	Readings	Assignments
1	Technology integration into science education	Dede, C. (2000). Emerging influences of information technology on school curriculum. *Journal of Curriculum Studies*, *32*(2), 281-303. Keengwe, J., & Onchwari, G. (2011). Fostering meaningful student learning through constructivist pedagogy and technology integration. *International Journal of Information and Communication Technology Education*, *7*(4), 1-10.	First lesson plan Reflections on the readings Article/News/ Activity Share Feedback on the lesson and each other's lesson plans
2	Technological Pedagogical Content Knowledge (TPACK) framework	Koehler, M. J., Mishra, P., & Cain, W. (2013). What is technological pedagogical content knowledge (TPACK)? *Journal of Education, 193*(3), 13-20. Koehler, M. J., Shin, T.S., & Mishra, P. (2011). How do we measure TPACK? Let me count the ways. In R. N. Ronau, C.R. Rakes, & M. L. Niess (Eds.) *Educational Technology, Teacher Knowledge, and Classroom Impact: A Research Handbook on Frameworks and Approaches*. Information Science Reference, Hershey PA. Graham, C. R. (2011). Theoretical considerations for understanding technological pedagogical content knowledge (TPACK). *Computers & Education*, *57*(3), 1953-1960.	Reflections on the readings Article/News/ Activity Share Feedback on lesson
3	TPACK literature review: What does the research say?	Baran, E., & Canbazoğlu Bilici S. (2015). Teknolojik Pedagojik Alan Bilgisi (TPAB) Üzerine Alanyazın İncelemesi: Türkiye Örneği. [in Turkish]. *Hacettepe Üniversitesi Eğitim Fakültesi Dergisi [Hacettepe University Journal of Education], 30*(1), 15-32. Voogt, J., Fisser, P., Pareja Roblin, N., Tondeur, J., & van Braak, J. (2013). Technological pedagogical content knowledge–a review of the literature. *Journal of Computer Assisted Learning*, *29*(2), 109-121.	Reflections on the readings Article/News/ Activity Share Feedback on lesson

4	TPACK in science education/science teacher education	Jimoyiannis, A. (2010). Designing and implementing an integrated technological pedagogical science knowledge framework for science teachers' professional development. *Computers & Education*, *55*(3), 1259-1269. McCrory, R. (2008). Science, technology, and teaching: The topic-specific challenges of TPCK in science. In AACTE Committee on Innovation and Technology (Ed.), *Handbook of Technological Pedagogical Content Knowledge (TPCK) for Educators* (pp. 193-206). New York: Published by Routledge for the American Association of Colleges for Teacher Education.	Reflections on the readings Article/News/ Activity Share Feedback on lesson
5	Examination of technology integrated science lesson examples	Harris, J.B., Mishra, P. & Koehler, M. (2009). Teachers' technological pedagogical content knowledge and learning activity types: Curriculum-based technology integration reframed. *Journal of Research on Technology in Education*, *41*(4), 393-416. Blanchard, M. R., Harris, J., & Hofer, M. (2011, February). *Science learning activity types.* Retrieved from College of William and Mary, School of Education, Learning Activity Types Wiki: http://activitytypes.wmwikis.net/file/view/ScienceLearningATs-Feb2011.pdf Herrington, J., & Kervin, L. (2007). Authentic learning supported by technology: Ten suggestions and cases of integration in classrooms. *Educational Media International*, *44*(3), 219-236.	Second lesson plan Reflections on the readings Article/News/ Activity Share Feedback on the lesson and each other's lesson plans
6	Online lab.s Simulations Games	van Joolingen, W. R., de Jong, T., Lazonder, A. W., Savelsbergh, E. R., & Manlove, S. (2005). Co-Lab: research and development of an online learning environment for collaborative scientific discovery learning. *Computers in human behavior*, *21*(4), 671-688.	Reflections on the readings Article/News/ Activity Share Feedback on lesson
7	Mobile applications Google services	Looi, C. K., Sun, D., Seow, P., & Chia, G. (2014). Enacting a technology-based science curriculum across a grade level: The journey of teachers' appropriation. *Computers & Education*, 71, 222-236.	Reflections on the readings Article/News/ Activity Share Feedback on lesson

8	Social media Presentation programs	Bull, G., Thompson, A., Searson, M., Garofalo, J., Park, J., Young, C., & Lee, J (2008). Connecting informal and formal learning: Experiences in the age of participatory media. *Contemporary Issues in Technology and Teacher Education*, *8*(2), 100-107. Açıkalın, F. S. (2011). Why Turkish pre-service teachers prefer to see powerpoint presentations in their classes. *TOJET: The Turkish Online Journal of Educational Technology*, 10(3), 340-347.	Reflections on the readings Article/News/ Activity Share Feedback on lesson
9	Wiki platforms Discussion groups Collaborative platforms	Parker, K., & Chao, J. (2007). Wiki as a teaching tool. *Interdisciplinary Journal of e-learning and Learning Objects*, *3*(1), 57-72. Reeves, T. C., Herrington, J., & Oliver, R. (2004). A development research agenda for online collaborative learning. *Educational Technology Research and Development*, *52*(4), 53-65.	Reflections on the readings Article/News/ Activity Share Feedback on lesson
10	Micro-teaching	Kim, M. C., Hannafin, M. J., & Bryan, L. A. (2007). Technology-enhanced inquiry tools in science education: An emerging pedagogical framework for classroom practice. *Science Education*, *91*(6), 1010-1030.	Third lesson plan Reflections on the readings Article/News/ Activity Share Feedback on the lesson and each other's micro-teachings
11	Micro-teaching	Guzey, S. S., & Roehrig, G. H. (2009). Teaching Science with Technology: Case Studies of Science Teachers' Development of Technological Pedagogical Content Knowledge (TPCK). *Contemporary Issues in Technology and Teacher Education*, *9*(1), 25-45.	Third lesson plan Reflections on the readings Article/News/ Activity Share Feedback on the lesson and each other's micro-teachings
12	Micro-teaching	So, H. J., & Kim, B. (2009). Learning about problem based learning: Student teachers integrating technology, pedagogy, and content knowledge. *Australasian Journal of Educational Technology*, *25*(1).	Third lesson plan Reflections on the readings Article/News/ Activity Share Feedback on lesson

13	Micro-teaching	Hew, K. F., & Brush, T. (2007). Integrating technology into K-12 teaching and learning: Current knowledge gaps and recommendations for future research. *Educational Technology Research and Development*, *55*(3), 223-252.	Third lesson plan Reflections on the readings Article/News/ Activity Share Feedback on lesson
14	No class ☺	No readings ☺	Fourth lesson plan Feedback on the course (general)

B. LESSON PLAN FORMAT

Grade level: Which grade level do you intend to teach with this lesson plan?

Duration: How long will it take to implement this lesson plan?

Objectives: Write down the objectives of this lesson. Please be specific. You are expected to determine your objectives aligned with the objectives given in the curriculum; you can revise them or add other objectives as long as you stay in the scope of the curriculum objectives.

Content: Which science content from the curriculum do you intend to teach with this lesson plan? Write the name of the topic and unit according to the curriculum. Give some background information about the content. Please also explain:

1. Why did you choose that specific topic to teach?
2. What might be the possible misconceptions that students have before they come to class?
3. What prior knowledge do you expect students to know related to that topic before they come to the class?
4. What are the possible difficulties you might face while teaching that topic?

Teaching Method(s): Which teaching method(s) will be used to teach that content? What are the important characteristics of that teaching method? Please also explain:

1. Why did you choose that specific teaching method?
2. Why do you think this method can be effective in teaching that content?
3. According to you, what are the advantages and disadvantages of this teaching method?

Instructional Technology(s): Which instructional technology(s) will be used to teach that content with that teaching method? Please also explain:

1. Why did you choose that specific instructional technology?

2. How do you think this instructional technology can improve the quality of teaching and learning?
3. What might be the possible advantages and disadvantages of integrating that instructional technology into teaching that content?
4. What other technologies might fit to that content and teaching method?

Teaching procedure: Please explain how you plan to carry out the whole lesson. Try to give as much details as possible. Clearly explain how you integrate the content, teaching method, and technology by giving details about the content to be taught, characteristics of the teaching method, and technology. You are advised to divide this part into sections as (1) introduction – middle - closure; (2) 0-10 min – 10-20 min – 20-30 min, and so on; (3) according to the steps of your teaching method; or (4) in any other way you think that is appropriate.

Assessment: How are you going to assess whether you reached your objectives or not? Please also explain:

1. Why did you choose that specific assessment strategy(s)?
2. How does your assessment strategy(s) fit your objectives?

C. INTERVIEW PROTOCOLS

C1. 1st Interview Protocol

1. Hazırladığınız fen öğretimi ders planlarında, öğreteceğiniz konuyu seçerken ne gibi kriterlere dikkat ettiniz?
    - Sizce bu konuyu anlatmak için başka hangi öğretim yöntemleri kullanılabilir? Neden?
    - Sizce bu konuyu öğretirken başka ne tür teknolojilerden faydalanılabilir? Neden?
2. Hazırladığınız fen öğretimi ders planlarında, entegre ettiğiniz teknolojiyi seçerken ne gibi kriterlere dikkat ettiniz?
    - Sizce bu teknoloji öğrencilerin fen konularını öğrenmesine nasıl yardımcı olur?
    - Bu teknolojiyi ders planınıza entegre ederken sizi en çok ne zorladı?
    - Bu ders planını gerçek bir sınıf ortamında uygulamanız gerekirse, teknoloji kullanımıyla ilgili nelerden endişe duyarsınız? Ne gibi sorunlarla karşılaşabilirsiniz?
    - Diyelim ki bu ders planını uyguluyorsunuz ve teknoloji sorun çıkardı, bu durumu nasıl çözersiniz?
    - Ders planınızda teknoloji kullanmanız mecbur tutulmasaydı, yine de bu teknolojiyi kullanır mıydınız?
3. Hazırladığınız fen öğretimi ders planlarında, kullandığınız öğretim yöntemini seçerken ne gibi kriterlere dikkat ettiniz?
    - Sizce bu öğretim yöntemi öğrencilerin fen konularını öğrenmesine nasıl yardımcı olur?
    - Bu öğretim yöntemini ders planınıza entegre ederken sizi en çok ne zorladı?
    - Bu ders planını gerçek bir sınıf ortamında uygulamanız gerekirse, öğretim yöntemiyle ilgili nelerden endişe duyarsınız? Ne gibi sorunlarla karşılaşabilirsiniz?

4. Ders planınızı hazırlarken önce konuyu mu, öğretim yöntemini mi yoksa teknolojiyi mi seçtiniz? Üçü nasıl bir araya geldi?
5. Hazırladığınız ders planı ile ilgili sizin eklemek istediğiniz bir şeyler var mı?

C2. 2nd Interview Protocol

1. Hazırladığınız fen öğretimi ders planlarında, öğreteceğiniz konuyu seçerken ne gibi kriterlere dikkat ettiniz?
   - Sizce bu konuyu anlatmak için başka hangi öğretim yöntemleri kullanılabilir? Neden?
   - Sizce bu konuyu öğretirken başka ne tür teknolojilerden faydalanılabilir? Neden?
2. Hazırladığınız fen öğretimi ders planlarında, entegre ettiğiniz teknolojiyi seçerken ne gibi kriterlere dikkat ettiniz?
   - Sizce bu teknoloji öğrencilerin fen konularını öğrenmesine nasıl yardımcı olur?
   - Bu teknolojiyi ders planınıza entegre ederken sizi en çok ne zorladı?
   - Bu ders planını gerçek bir sınıf ortamında uygulamanız gerekirse, teknoloji kullanımıyla ilgili nelerden endişe duyarsınız? Ne gibi sorunlarla karşılaşabilirsiniz?
   - Diyelim ki bu ders planını uyguluyorsunuz ve teknoloji sorun çıkardı, bu durumu nasıl çözersiniz?
   - Ders planınızda teknoloji kullanmanız mecbur tutulmasaydı, yine de bu teknolojiyi kullanır mıydınız?
3. Hazırladığınız fen öğretimi ders planlarında, kullandığınız öğretim yöntemini seçerken ne gibi kriterlere dikkat ettiniz?
   - Sizce bu öğretim yöntemi öğrencilerin fen konularını öğrenmesine nasıl yardımcı olur?

- Bu öğretim yöntemini ders planınıza entegre ederken sizi en çok ne zorladı?
- Bu ders planını gerçek bir sınıf ortamında uygulamanız gerekirse, öğretim yöntemiyle ilgili nelerden endişe duyarsınız? Ne gibi sorunlarla karşılaşabilirsiniz?

4. Ders planınızı hazırlarken önce konuyu mu, öğretim yöntemini mi yoksa teknolojiyi mi seçtiniz? Üçü nasıl bir araya geldi?
5. Bir önceki ders planınızla karşılaştırdığınızda bu ders planınızda ne gibi farklılıklar yaptınız? Daha mı kolay hazırladınız, daha mı zor?
6. Hazırladığınız ders planı ile ilgili sizin eklemek istediğiniz bir şeyler var mı?

C3. 3rd Interview Protocol

1. Hazırladığınız fen öğretimi ders planlarında, öğreteceğiniz konuyu seçerken ne gibi kriterlere dikkat ettiniz?
   - Sizce bu konuyu anlatmak için başka hangi öğretim yöntemleri kullanılabilir? Neden?
   - Sizce bu konuyu öğretirken başka ne tür teknolojilerden faydalanılabilir? Neden?
2. Hazırladığınız fen öğretimi ders planlarında, entegre ettiğiniz teknolojiyi seçerken ne gibi kriterlere dikkat ettiniz?
   - Sizce bu teknoloji öğrencilerin fen konularını öğrenmesine nasıl yardımcı olur?
   - Bu teknolojiyi ders planınıza entegre ederken sizi en çok ne zorladı?
   - Bu ders planını gerçek bir sınıf ortamında uygulamanız gerekirse, teknoloji kullanımıyla ilgili nelerden endişe duyarsınız? Ne gibi sorunlarla karşılaşabilirsiniz?
   - Diyelim ki bu ders planını uyguluyorsunuz ve teknoloji sorun çıkardı, bu durumu nasıl çözersiniz?

- o Ders planınızda teknoloji kullanmanız mecbur tutulmasaydı, yine de bu teknolojiyi kullanır mıydınız?

3. Hazırladığınız fen öğretimi ders planlarında, kullandığınız öğretim yöntemini seçerken ne gibi kriterlere dikkat ettiniz?
   - o Sizce bu öğretim yöntemi öğrencilerin fen konularını öğrenmesine nasıl yardımcı olur?
   - o Bu öğretim yöntemini ders planınıza entegre ederken sizi en çok ne zorladı?
   - o Bu ders planını gerçek bir sınıf ortamında uygulamanız gerekirse, öğretim yöntemiyle ilgili nelerden endişe duyarsınız? Ne gibi sorunlarla karşılaşabilirsiniz?
4. Ders planınızı hazırlarken önce konuyu mu, öğretim yöntemini mi yoksa teknolojiyi mi seçtiniz? Üçü nasıl bir araya geldi?
5. Bir önceki ders planınızla karşılaştırdığınızda bu ders planınızda ne gibi farklılıklar yaptınız? Daha mı kolay hazırladınız, daha mı zor?
6. Hazırladığınız ders planı ile ilgili sizin eklemek istediğiniz bir şeyler var mı?
7. Ders anlatımı esnasında neler yaşadınız?
8. Ders anlatımında sizi en çok zorlayan kısım neydi?
9. Aynı ders anlatımını gerçek bir sınıfta o yaş grubu öğrencilerle yapabilir misiniz? Neleri değiştirirsiniz?
10. Ders planınızda yazıp uygulama esnasında yapamadığınız kısımlar oldu mu? Olduysa hangi kısımlardı?
11. Bu ders planının anlatımını yapacağınız için ders planınıza eklemekten vazgeçtiğiniz şeyler oldu mu? Olduysa nelerdi?
12. Ders anlatımınız ile ilgili ile ilgili sizin eklemek istediğiniz bir şeyler var mı?

C4. 4th Interview Protocol

1. Hazırladığınız fen öğretimi ders planlarında, öğreteceğiniz konuyu seçerken ne gibi kriterlere dikkat ettiniz?
    - Sizce bu konuyu anlatmak için başka hangi öğretim yöntemleri kullanılabilir? Neden?
    - Sizce bu konuyu öğretirken başka ne tür teknolojilerden faydalanılabilir? Neden?
2. Hazırladığınız fen öğretimi ders planlarında, entegre ettiğiniz teknolojiyi seçerken ne gibi kriterlere dikkat ettiniz?
    - Sizce bu teknoloji öğrencilerin fen konularını öğrenmesine nasıl yardımcı olur?
    - Bu teknolojiyi ders planınıza entegre ederken sizi en çok ne zorladı?
    - Bu ders planını gerçek bir sınıf ortamında uygulamanız gerekirse, teknoloji kullanımıyla ilgili nelerden endişe duyarsınız? Ne gibi sorunlarla karşılaşabilirsiniz?
    - Diyelim ki bu ders planını uyguluyorsunuz ve teknoloji sorun çıkardı, bu durumu nasıl çözersiniz?
    - Ders planınızda teknoloji kullanmanız mecbur tutulmasaydı, yine de bu teknolojiyi kullanır mıydınız?
3. Hazırladığınız fen öğretimi ders planlarında, kullandığınız öğretim yöntemini seçerken ne gibi kriterlere dikkat ettiniz?
    - Sizce bu öğretim yöntemi öğrencilerin fen konularını öğrenmesine nasıl yardımcı olur?
    - Bu öğretim yöntemini ders planınıza entegre ederken sizi en çok ne zorladı?
    - Bu ders planını gerçek bir sınıf ortamında uygulamanız gerekirse, öğretim yöntemiyle ilgili nelerden endişe duyarsınız? Ne gibi sorunlarla karşılaşabilirsiniz?

4. Ders planınızı hazırlarken önce konuyu mu, öğretim yöntemini mi yoksa teknolojiyi mi seçtiniz? Üçü nasıl bir araya geldi?
5. Bir önceki ders planınızla karşılaştırdığınızda bu ders planınızda ne gibi farklılıklar yaptınız? Daha mı kolay hazırladınız, daha mı zor?
6. Hazırladığınız ders planı ile ilgili sizin eklemek istediğiniz bir şeyler var mı?
7. Dersin organizasyonunu değerlendirecek olursanız (teori, uygulama, micro-teaching) neler söyleyebilirsiniz? Sizce değişmesi gereken kısımlar neler?
8. Derste yaptığımız etkinlikler (delphi çalışması, tpack game, teknoloji sunumları vd.) hakkında neler düşünüyorsunuz?
9. Dersin assignmentlarını değerlendirecek olursanız neler söyleyebilirsiniz? Eklenmeli mi yoksa azaltılmalı mı? Dönem içine yayılması iyi mi yoksa onun yerine dönem sonunda daha kapsamlı bir ödev mi olmalı?
10. Bu dersi almaya düşünen biri (hem graduate hem pre-service) fikrinizi sorduğunda al ya da alma derken neler söylersiniz?
11. Dersle ilgili sizin eklemek istediğiniz bir şeyler var mı?

D. TPACK LEVELS RUBRIC

C1: An overarching conception about the purposes for incorporating technology in teaching subject matter topics	
Level	**Explanation**
Recognizing (1)	– Instructional technology is used for motivation, rather than actual subject matter development. All learning of new ideas presented by the teacher mostly without technology. – Technology-based activities do not include inquiry tasks. Technology procedures concentrate on drills and practice only.
Accepting (2)	– Instructional technology is used for motivation, rather than actual subject matter development. Larger part of technology use is for demonstrations, which include presenting new knowledge. – Technology-based activities do not include inquiry tasks. Technology procedures concentrate on teacher demonstration and practice.
Adapting (3)	– Teacher is one who is using instructional technology in a way that is new and different from teaching without technology and students use technology for learning new knowledge. – Technology-based activities include inquiry tasks. Technology procedures concentrate on scientific tasks with connections and on inquiry activities that use or develop connections.
Exploring (4)	– Larger part of instructional technology use is by students who explore and experiment with it for new knowledge and for practice. – Technology-based activities include inquiry tasks. Technology procedures concentrate on scientific tasks with connections and on inquiry activities that use or develop connections. Technology procedures concentrate on doing science.
Advancing (5)	– Instructional technology tasks provide students with deeper conceptual understanding of science and their processes. – Technology-based activities include inquiry tasks of high cognitive demand. Technology procedures concentrate on scientific tasks with connections and on doing science. Technology procedures concentrate on inquiry activities that use or develop deep scientific knowledge representing connections and strategic knowledge.

C2: Knowledge of students' understandings, thinking, and learning in subject matter topics with technology	
Level	**Explanation**
Recognizing (1)	– Instructional technology is used primarily for student practice. – Digital materials do not present any new material, and only provides space for applications and drills.
Accepting (2)	– Instructional technology is mostly used for teacher demonstrations or teacher-led student-follow work with technology; it is rarely used for students' independent explorations. Teacher sees the technology as a motivational tool for student rather than a learning tool. – Digital materials mirror the structure of the textbook presentation of science without active explorations.
Adapting (3)	– Teacher focuses on students' thinking of science while students are using instructional technology on their own – both for learning new knowledge and review of prior knowledge. – Digital materials provide an environment for students to do science with teacher guidance.
Exploring (4)	– Instructional technology focuses on students' science conceptual understanding and serves as a guide for student learning with technology, not a director. – Digital materials provide an environment for students to deliberately take scientifically meaningful actions on objects. Teacher guidance is necessary in order for students to see the scientifically meaningful consequences of those actions.
Advancing (5)	– Teacher facilitates students' high level thinking with instructional technology. – Digital materials provide an environment for students to deliberately take scientifically meaningful actions on objects and to immediately see the scientifically meaningful consequences of those actions.

C3: Knowledge of curriculum and curricular materials that integrate technology in learning and teaching subject matter topics	
Level	**Explanation**
Recognizing (1)	– Teacher does not use instructional technology for learning science. – Instructional technology if used is not aligned with one or more curriculum goals.
Accepting (2)	– Teacher uses standard approach to the curriculum topics with instructional technology being used as add-on. – Instructional technology is partially aligned with one or more curriculum goals. Teacher has difficulty in identifying topics in science curriculum for including instructional technology as tool.
Adapting (3)	– The instructional technology is used as a replacement for non-technology based tasks in a traditional curriculum approach. Teacher only adapts experiences that he/she has personally experienced in his/her learning. – Instructional technology is aligned with one or more curriculum goals. Teacher chooses topics from school science curricula; however, technology use is not always appropriate for the chosen curriculum topics.
Exploring (4)	– Teacher envisions on his/her own as to how curriculum might be taught with the technology. Students are given problem-solving tasks with instructional technology and are asked to expand science ideas based on technology explorations. – Technology is aligned with curriculum goals. Teacher chooses important topics of school science curricula and technology use is appropriate for the chosen curriculum topics.
Advancing (5)	– Teacher uses instructional technology in a fully constructive way, including tasks for development of higher-level thinking and deepening understanding of science concepts. Teacher challenges the traditional curriculum - engaging students in learning quite different topics with the technology and eliminating some of the topics that have traditionally been taught. – Instructional technology is strongly aligned with curriculum goals. Teacher chooses essential topics of school science curricula. Technology use is effective for the chosen curriculum topics.

C4: Knowledge of instructional strategies and representations for teaching and learning subject matter topics with technologies	
Level	**Explanation**
Recognizing (1)	– Teacher focuses on how to use instructional technology rather than how to explore science ideas, using teacher-directed lectures followed by student practice. – Digital materials provide students only with opportunities for drill and practice.
Accepting (2)	– The instructions are teacher-led. Teacher structures lesson plan with limited student explorations with instructional technology. – Digital materials are not built around learning objects and do not promote student reflection.
Adapting (3)	– Teacher uses deductive (teacher- directed) approach to teaching with instructional technology to maintain control of the progression of the activities. – Digital materials are built around learning objects but do not promote student reflection – especially the posing of questions for sense making.
Exploring (4)	– Teacher uses various instructional strategies (deductive and inductive) and focuses on students thinking about science. Teacher's use of instructional technology is beyond traditional approaches to curricular topics. – Digital materials are built around learning objects and must explicitly promote student reflection – especially the posing of questions for sense making.
Advancing (5)	– Teacher focuses on students' hands-on and experimentation of new science ideas with instructional technology, and focuses on conceptual development. – Digital materials are built around learning objects and must explicitly promote student reflection – especially the posing of questions for sense making and reasoning, including explanation and justification.

E. ETHICAL COMMITTEE APPROVAL

UYGULAMALI ETİK ARAŞTIRMA MERKEZİ
APPLIED ETHICS RESEARCH CENTER

ORTA DOĞU TEKNİK ÜNİVERSİTESİ
MIDDLE EAST TECHNICAL UNIVERSITY

DUMLUPINAR BULVARI 06800
ÇANKAYA ANKARA/TURKEY
T: +90 312 210 22 91
F: +90 312 210 79 59
Sayı: 28620816 / 358
www.ueam.metu.edu.tr

13 EKİM 2015

Gönderilen: Prof. Dr. Jale ÇAKIROĞLU

İlköğretim Ana Bilim Dalı

Gönderen: Prof. Dr. Canan SÜMER

İnsan Araştırmaları Komisyonu Başkanı

İlgi: Etik Onayı

Danışmanlığını yapmış olduğunuz İlköğretim Ana Bilim Dalında Doktora Öğrencisi Gamze ÇETİNKAYA AYDIN "Fen Bilgisi Öğretmeni Eğitiminde Teknolojik Pedagojik Alan Bilgisi (Technological Pedagogical Content Knowledge in Science Teacher Education)" isimli araştırması İnsan Araştırmaları Komisyonu tarafından uygun görülerek gerekli onay 13.10.2015 - 13.06.2016 tarihleri arasında geçerli olmak üzere verilmiştir.

Bilgilerinize saygılarımla sunarım.

Prof. Dr. Canan SÜMER
Uygulamalı Etik Araştırma Merkezi
İnsan Araştırmaları Komisyonu Başkanı

F. CONSENT FORM

Gönüllü Katılım Formu

Bu çalışma, ODTÜ İlköğretim Bölümü öğretim üyesi Prof. Dr. Jale ÇAKIROĞLU danışmanlığında, Arş. Gör. Gamze Çetinkaya AYDIN tarafından yürütülen bir doktora tez çalışmasıdır. Bu form sizi araştırma koşulları hakkında bilgilendirmek için hazırlanmıştır.

Bu çalışmanın amacı, ilköğretim bölümünde verilmekte olan "ESME 522 - Teaching Science with Technology" dersinin, dersi alan öğrencilerin teknolojik pedagojik alan bilgilerinin gelişimini sağlama açısından etkililiğini incelemektir. Bu amaç doğrultusunda dersi alan öğrencilerden anket, mülakat (ses kaydı), gözlem (video kaydı) ve ders kapsamında hazırlanan materyaller yoluyla veri toplanacaktır. Toplanan bu veriler, dersin geliştirilmesi ve daha iyi hale getirilmesi amacıyla kullanılacaktır.

Çalışmanın fiziksel ve ruhsal sağlığınız için herhangi bir riski bulunmamaktadır. Çalışmaya katılımınız tamamıyla gönüllülük esasına dayalıdır. Cevaplarınız tamamıyla gizli tutulacak ve sadece araştırmacılar tarafından değerlendirilecektir; elde edilecek bilgiler yalnızca bilimsel yayımlarda kullanılacaktır. Hiçbir şekilde gerçek isminiz kullanılmayacak, kimseyle paylaşılmayacaktır. Anket, görüşme ve raporlarda kişisel anlamda rahatsızlık verici sorular bulunmamaktadır. Ancak, herhangi bir nedenden ötürü kendinizi rahatsız hissederseniz, soruları yanıtlamayı bırakabilir ve herhangi bir gerekçe belirtmeden ayrılabilirsiniz. Çalışmaya katılma, çalışmaya katılmama ya da çalışmayı yarım bırakma durumları herhangi bir olumsuzluk yaratmayacak ve ders notlarınıza asla etki etmeyecektir.

Çalışmada sizden beklenen aktivitelere aktif katılım sağlamanız, sorulara içtenlikle yanıt vermeniz ve ders için hazırladığınız materyallerin çalışma kapsamında değerlendirilmesine izin vermenizdir. Katılımınız için şimdiden teşekkür ederiz. Çalışma hakkında daha fazla bilgi almak için İlköğretim Bölümü araştırma görevlilerinden Gamze ÇETİNKAYA AYDIN ile iletişim kurabilirsiniz.

Bu çalışmaya tamamen gönüllü olarak katılıyorum ve istediğim zaman yarıda kesip çıkabileceğimi biliyorum. Verdiğim bilgilerin bilimsel amaçlı yayımlarda kullanılmasını kabul ediyorum. (Formu doldurup imzaladıktan sonra uygulayıcıya geri veriniz).

İsim Soyad	Tarih	İmza

G. CURRICULUM VITAE

Gamze ÇETİNKAYA AYDIN
gamzecetinkaya@gmail.com

WORK EXPERIENCE

10.2021 – 01.2022	Part-time Instructor TED University
08.2020 – 03.2021	Research Assistant METU, Department of Math. and Science Education, Science Education
01.2019 – 06.2020	Education Specialist Türk Eğitim Derneği / TEDMEM
09.2011 – 10.2018	Research Assistant METU, Department of Math. and Science Education, Science Education
03.2010 – 09.2011	Research Assistant Sakarya Uni., Department of Math. and Science Education, Science Education

EDUCATION

2022	Ph.D.	Middle East Technical University, Graduate School Of Social Sciences, Elementary Education, CGPA: 4.00
2012	M.S.	Middle East Technical University, Graduate School Of Social Sciences, Elementary Science and Mathematics Education, CGPA: 3.86 / 4.00
2009	B.S.	Middle East Technical University, Faculty of Education, Elementary Science Education, CGPA: 3.33 / 4.00

PROJECTS

- Researcher – University Supported Scientific Research Project (BAP1), METU-BAP Coordination, "Elementary students' perceptions of scientists and engineers and their interests towards STEM careers", 01.2018-12.2018. (Project no: GAP-501-2018-3014)
- Researcher – European Union Project, "Make It Real - Addressing underachievement in STEAM education through real product design and making practices", 12.2016 –12.2018. (Project no: Erasmus+ KA2 Project| 2016-1-PL01-KA201-026492)
- Researcher – European Union Project, "GREEEN - Green Environment Education European Network", 12.2013 – 12.2016. (Project no: 539963-LLP-1-2013-1-DE-COMENIUS-CNW)
- Researcher – University Supported Scientific Research Project (BAP1), METU-BAP Coordination, "Evaluation of Pre-service Science Teachers' Dispositions towards STEM Education with regard to Cognitive and Affective Variables", 06.2016-12.2016. (Project no: BAP-05-06-2016-009)
- Staff – TÜBİTAK 2229 Project, "Genç Mucitler Geleceği Tasarlıyor", 7,8,14,15,21 March 2015.

PUBLICATIONS

Book Chapters

Çetinkaya-Aydın, G., & Çakıroğlu, J. (2019). Fen Bilimleri Öğretiminde Teknoloji Kullanımı. In D. Akgündüz (Eds.), *Fen ve Matematik Eğitiminde Teknolojik Yaklaşımlar* (pp. 57-73). Anı Yayıncılık.

International Journal Papers

Çetinkaya-Aydın, G., & Çakıroğlu, J. (2017). Learner Characteristics and Understanding Nature of Science. *Science & Education, 26*(7-9), 919-951.

Yiğit, E. A., Kıyıcı, F. B., & Çetinkaya, G. (2014). Evaluating the Testing Effect in the Classroom: An Effective Way to Retrieve Learned Information. *Journal of Educational Research, 54,* 99-116.

International Conference Papers

Çetinkaya-Aydın, G., & Çakıroğlu, J. (2022, September 1–10). *The Effect of a Graduate Course on Science Teachers' Self-Efficacy and Perceived Competencies of TPACK*. ECER Plus Online.

Çetinkaya-Aydın, G., Sicim, B., & Yılmaz, S. (2017, August 21–25). *STEM instruction in the early childhood classroom: A case from Turkey.* European Conference on Educational Research, Copenhagen, Denmark.

Çetinkaya-Aydın, G. (2017, May 18–21). *Investigation of pedagogical orientations of pre-service science teachers*. ERPA International Congresses on Education, Budapest, Hungary.

Çakıroğlu, J., & Yılmaz-Tüzün, Ö., & Çetinkaya-Aydın, G. (2017, May 18–21). *Investigation of pre-service science teachers' perceptions of integrated STEM education.* ERPA International Congresses on Education, Budapest, Hungary.

Yılmaz, S., Sicim, B., & Çetinkaya-Aydın, G. (2017, May 18–21). *Pre-service teachers' environmental literacy in terms of knowledge, attitude, concern and responsibility.* ERPA International Congresses on Education, Budapest, Hungary.

Çetinkaya-Aydın, G., & Sicim, B. (2015, September 7–11). *Pre-service Elementary Teachers' Self-Perceptions of TPACK and Intentions of Technology Use: Is There A Correlation?.* European Conference on Educational Research Budapest, Hungary.

Çetinkaya-Aydın, G., Evren, E., Atakan, İ., Şen, M., Yılmaz, B., Pirgon, E.,…,Ebren, E. (2015, June, 4–7). *Delphi technique as a graduate course activity: Elementary science teachers' TPACK competencies*. ERPA International Congresses on Education, Athens, Greece.

Mehmetlioğlu, D., & Çetinkaya-Aydın, G. (2015, June, 4–7). *Music integration into early childhood mathematics: Beliefs and attitudes of pre-service early childhood education teachers.* ERPA International Congresses on Education, Athens, Greece.

Çetinkaya-Aydın, G. (2014, October 29 – Novermber 2). *Technological pedagogical content knowledge in science teacher education*. iSER 2014 World Conference, Nevşehir, Turkey.

Çakıroğlu, J., & Çetinkaya, G. (2014, July, 14–17). *The association between understanding nature of science and science teaching self-efficacy beliefs*. Twenty-first International Conference on Learning, New York, USA.

Çetinkaya, G., & Çakıroğlu, J. (2013, September 9–13). *Understanding nature of science and metacognitive awareness: Is there an association?*. European Conference on Educational Research, İstanbul, Turkey.

Çetinkaya, G., Çakıroğlu, J., & Yılmaz-Tüzün, Ö. (2013, September 9–13). *The interaction between nature of science understanding and religious beliefs*. European Conference on Educational Research, İstanbul, Turkey.

Karaduman, M. A., Kıran, D., Çetinkaya, G. (2013, September 9–13). *A comparison of nature of science understandings of preservice early childhood and science teachers*. European Conference on Educational Research, İstanbul, Turkey.

Çetinkaya, G., & Çakıroğlu, J. (2013, April 6–9). *Relationship between pre-service elementary science teachers' understandings of nature of science and faith developments*. National Association for Research in Science Teaching Conference, Puerto Rico, USA.

Çetinkaya, G., & Çakıroğlu, J. (2012, September, 13–15). *Pre-service science teachers' views of nature of science and scientific inquiry.* Applied Education Congress (APPED), Ankara, Turkey.

Çetinkaya, G., & Çakıroğlu, J. (2011, September 5–9). *Pre-service science and primary school teachers' perceptions of science laboratory environment.* European Science Education Research Association (ESERA) Conference, Lyon, France.

Kurbanoğlu, N.İ., Takunyacı, M., Kocaman, O., & Çetinkaya, G. (2010, April 26–28). *The Turkish adaptation of e-learning attitude scale: Reliability and validity studies.* International Educational Technology Conference (IETC), İstanbul, Turkey.

<u>National Conference Papers</u>

Çetinkaya, G., & Karışan, D. (2012, June 27–30). *Fen bilgisi öğretmen adaylarının bilimin doğası hakkındaki görüşleri ve bilimin doğasına ilişkin üstbilişsel yetenekleri arasındaki ilişkinin incelenmesi*. X. Ulusal Fen Bilimleri ve Matematik Eğitimi Kongresi, Niğde, Turkey.

Contributed Work In TEDMEM:

TEDMEM. (2020). *COVID-19 sürecinde eğitim: Uzaktan öğrenme, sorunlar ve çözüm önerileri* (TEDMEM Analiz Dizisi 7). Ankara: Türk Eğitim Derneği Yayınları. https://tedmem.org/yayin/covid-19-surecinde-egitim-uzaktan-ogrenme-sorunlar-cozum-onerileri

TEDMEM. (2020). *2019 eğitim değerlendirme raporu* (TEDMEM Değerlendirme Dizisi 6). Ankara: Türk Eğitim Derneği. https://tedmem.org/yayin/2019-egitim-degerlendirme-raporu

TEDMEM. (2020, June 29). *Türkiye'de okul türlerine göre öğrencilerin okul yaşamı nasıl farklılaşıyor?* https://tedmem.org/mem-notlari/degerlendirme/turkiyede-okul-turlerine-gore-ogrencilerin-okul-yasami-nasil-farklilasiyor

TEDMEM. (2020, April 20). *COVID-19 salgını sürecinde öğretmenler.* https://tedmem.org/covid-19/covid-19-salgini-surecinde-ogretmenler

TEDMEM. (2020, January 7). *Doç. Dr. Işıl Kabakçı Yurdakul ile dijital çağda çocuklar ve eğitim üzerine.* https://tedmem.org/soylesi/doc-dr-isil-kabakci-yurdakul-ile-dijital-cagda-cocuklar-ve-egitim-uzerine

TEDMEM. (2019). *TALIS 2018 sonuçları ve Türkiye üzerine değerlendirmeler* (TEDMEM Analiz Dizisi 6). Ankara: Türk Eğitim Derneği Yayınları. https://tedmem.org/yayin/talis-2018-sonuclari-turkiye-uzerine-degerlendirmeler

TEDMEM. (2019). *2018 eğitim değerlendirme raporu* (TEDMEM Değerlendirme Dizisi 5). Ankara: Türk Eğitim Derneği. https://tedmem.org/yayin/2018-egitim-degerlendirme-raporu

TEDMEM. (2019, October 24). *İşlerin geleceği ve geleceğin işleri.* https://tedmem.org/mem-notlari/degerlendirme/islerin-gelecegi-gelecegin-isleri

TEDMEM. (2019, September 20). *Bir bakışta eğitim 2019.* https://tedmem.org/mem-notlari/degerlendirme/bir-bakista-egitim-2019

H. TURKISH SUMMARY / TÜRKÇE ÖZET

Giriş

Dijital teknolojilerin okullarda daha erişilebilir ve kullanılabilir hale gelmesiyle birlikte, teknolojik araçların sınıflarda kullanımında son yıllarda önemli ölçüde artış gerçekleşmiştir. Ancak teknolojik araçların sık kullanılması, teknolojinin öğretime entegrasyonunun başarılı olduğu anlamına gelmemektedir (Farjon vd., 2019). Teknolojilerin sınıfta var olması etkin kullanımını garanti etmemektedir, bu nedenle odak noktası teknolojinin öğretim süreçlerine anlamlı entegrasyonu olmalıdır (Graham ve diğerleri, 2009). Teknolojinin eğitim alanında anlamlı bir değişime yol açabilmesi için, öğretmenlerin teknolojiyi öğrenmeyi güçlendirecek bir şekilde etkin kullanabilmesi gerekmektedir. Gerekli pedagojik yetkinliklere sahip, teknolojiyi öğrenmeyi destekleyecek biçimde kullanabilen öğretmenler olmadan, teknoloji eğitime vaat ettiği katkıları sağlayamaz (Keengwe & Onchwari, 2011). Bu nedenle, teknolojinin etkin entegrasyonu için, öğretmenlerin teknoloji, pedagoji ve alan bilgisini öğrenme süreçlerini güçlendirecek şekilde bir araya getirebilecek yetkinliklere sahip olması gerekmektedir.

Bu nedenle, teknoloji, pedagoji ve alan bilgisi arasındaki etkileşimleri göz önünde bulundurarak teknolojinin etkili kullanımını açıklamaya çalışan, teknolojik pedagojik alan bilgisine (TPAB) (Örn., Angeli & Valanides, 2005; Mishra & Koehler, 2006; Niess, 2005) yönelik çeşitli kavramsal çerçeveler ortaya koyulmuştur. Özellikle Mishra ve Koehler (2006) tarafından geliştirilen kavramsal çerçeve oldukça kabul görmüş ve çok sayıda çalışmada kullanılmıştır. Bu kavramsal çerçevede, teknoloji, pedagoji ve alan bilgisi birbirinden bağımsız bilgi yapıları değildir; hepsi birbiriyle ilişkilidir ve öğretmenlerin temel bilgi yapısını oluşturur. Etkili teknoloji entegrasyonu için öğretmenlerin teknoloji, pedagoji ve alan bilgilerini bağlamsal faktörleri göz önünde bulundurarak anlamlı bir şekilde birleştirmesi gerekmektedir.

TPAB kavramsal çerçevesi farklı araştırmacılar tarafından iki farklı yaklaşımla ele alınmıştır. Birleştirici yaklaşımda TPAB kendisini oluşturan bilgi türlerinin toplamı olarak açıklanmaktadır. Buna göre, teknoloji bilgisi (TP), pedagoji bilgisi (PB), alan bilgisi (AB), teknolojik pedagojik bilgi (TPB), teknolojik alan bilgisi (TAP), ve pedagojik alan bilgisi (PAB) yüksek olan öğretmenlerin yüksek düzeyde TPAB'a sahip olması beklenmektedir (Schmid vd., 2020). Öte yandan, dönüşümcü yaklaşımda TPAB ayrı bir bilgi türü olarak ele alınmaktadır. TPAB bileşenleri olarak ifade edilen bilgilere sahip olmak TPAB gelişimi için gerekli ve önemlidir ancak yeterli değildir; bu bilgilere sahip olan öğretmenlerin otomatik olarak yüksek düzeyde TPAB sahibi olacağı varsayılamaz (Angeli, & Valanides, 2009; 2013; Chai vd., 2010; Graham, 2011).

Dönüşümcü yaklaşımı benimseyen Niess (2005), TPAB'ı tanımlamak için Grossman (1989, 1990) tarafından ortaya koyulan PAB bileşenlerini kullanmış ve teknolojinin etkili kullanımı için öğretmenlerin sahip olması gereken bilgi ve becerileri şu şekilde açıklamıştır:

1. Belirli bir konuyu teknoloji kullanarak öğretmenin ne anlama geldiğine dair kapsamlı bir anlayış;
2. Öğrencilerin belirli bir konuyu teknoloji yardımıyla anlama, düşünme ve öğrenmelerine yönelik bilgi;
3. Teknoloji entegrasyonuyla öğretilen alana ait öğretim programı ve materyallerine yönelik bilgi;
4. Belirli bir konuyu teknoloji yardımıyla öğretmek için kullanılan öğretim yöntem ve stratejileri bilgisi (Niess, 2005, s. 511).

Bu modele göre, öğretmenleri TPAB sahibi veya değil diye ayrıştırmak mümkün değildir; TPAP gelişimi bir bilişsel gelişim sürecidir ve fark etme, kabullenme, uyum sağlama, keşfetme ve ilerleme olmak üzere beş aşamada gerçekleşir. Bu çalışmada da öğretmenlerin TPAB gelişimlerini araştırmak için Niess (2005) tarafından önerilen bu TPAB modeli kullanılmıştır.

Araştırmalar mesleğe yeni başlayan öğretmenlerin teknolojiyi etkin kullanmak konusunda kendilerini yeterli hissetmediklerini göstermektedir (Tondeur vd., 2012). Bu nedenle, öğretmen yetiştirme programını yüksek seviyede TPAB sahibi öğretmenler mezun edecek şekilde dönüştürmek (Mouza, 2016) ve görev yapan öğretmenlerin TPAB düzeyini artırmaya yönelik hizmet içi eğitim programları tasarlamak (Baran vd., 2016) önemli araştırma konuları haline gelmiştir.

Bunun yanı sıra, etkili teknoloji entegrasyonu için gerekli bilgi ve beceriler öğretilen alan bilgisine göre değişebilmektedir; bu nedenle, TPAB geliştirmeye yönelik uygulamaların öğretilmesi hedeflenen alanı göz önünde bulundurması oldukça önemlidir (Graham vd., 2009). Fen eğitimi özelinde bakıldığında, etkili teknoloji kullanımı öğrencilerin derse katılımını artırma, öğretim süreçlerini geliştirme, ve öğrencilerin bilimsel kavramları anlamasını kolaylaştırma potansiyeline sahiptir (Bell vd., 2013). Fen öğretimi geliştirmeye yönelik pek çok teknolojik araç bulunmaktadır. Teknolojik araçların entegrayonu sayesinde soyut kavramlar somut hale getirilebilir, doğal olaylar daha hızlı veya yavaş, daha büyük ya da küçük ölçekte canlandırılarak öğrencilerin gözlem yapması sağlanabilir, ve deney sonuçları öğrencilerin çıkarım yapmasını kolaylaştıracak bir halde sunulabilir (Grimalt-Álvaro vd., 2019). Teknolojik araçların etkin kullanımı öğrencilerin araştırma tabanlı öğretim süreçlerine dahil olmasını kolaylaştırarak kendi bilgilerini yapılandırmalarına, fen konularını bilim insanı gibi davranarak öğrenmelerine ve problem çözme becerilerini geliştirmelerine yardımcı olabilir (Guzey, & Roehrig, 2009; Trowbridge vd., 2008).

Teknolojinin fen eğitimine sağlayabileceği potansiyel katkılar göz önüne alındığında, fen öğretmenlerinin yüksek düzeyde TPAB sahibi olmasının önemi daha açık hale gelmektedir. Ne yazık ki öğretmenlerin TPAB düzeylerini artırmanın tek bir mükemmel yolu yoktur. Öğretmenleri teknoloji etkin bir biçimde kullanmak için hazırlamak oldukça zorlu ve karmaşık bir süreçtir (Liu, 2016; Tondeur vd., 2012). Bu nedenle, fen öğretmenlerinin TPAB düzeylerini geliştirmeye yönelik alternatif programlar hazırlanması ve test edilmesi, etkili yöntemlerin belirlenmesi için oldukça önemlidir.

Bu noktadan hareketle, bu çalışmanın amacı fen öğretmenlerinin TPAB düzeylerini geliştirmeye yönelik bir yükseköğretim dersi geliştirmek ve bu dersin etkililiğini araştırmaktır. Bu kapsamda, öncelikle ilgili alan yazın taranmış ve öğretmenlerin TPAB düzeylerini artırmada etkili olduğu daha önceki araştırmalarda ortaya koyulmuş prensipler belirlenmiştir. Daha sonra bu prensipler çerçevesinde Teori – Alıştırma – Pratik (T-A-P) isimli bir ders tasarımı geliştirilmiş ve bu ders tasarımı iki ardışık dönem boyunca lisansüstü düzeydeki fen eğitimi öğrencilerine uygulanarak aşağıdaki araştırma sorularına yanıt aranmıştır:

1. Lisansüstü düzeydeki fen eğitimi öğrencilerinin T-A-P ders tasarımı çerçevesinde kurgulanan Teknoloji Destekli Fen Öğretimi dersi hakkındaki görüşleri nedir?
2. Lisansüstü düzeydeki fen eğitimi öğrencilerinin TPAB yeterlik algılarında ve öz yeterlik inanç düzeylerinde T-A-P ders tasarımı çerçevesinde kurgulanan Teknoloji Destekli Fen Öğretimi dersine katıldıktan sonra bir değişim var mıdır?
3. Lisansüstü düzeydeki fen eğitimi öğrencilerinin TPAB düzeyleri T-A-P ders tasarımı çerçevesinde kurgulanan Teknoloji Destekli Fen Öğretimi dersine katılımları süresince nasıl değişmiştir?

Bu çalışmanın fen öğretmenlerinin TPAB gelişimi desteklemede etkili yöntem ve stratejilerin belirlenmesi açısından alan yazına önemli katkılar sağlayacağı düşünülmektedir. Önceki araştırmalara etkili olduğu iddia edilen prensipleri bir araya getirerek ve fen eğitimi özelinde uyarlayarak bir ders tasarım modeli ortaya koyulmuştur. Bu ders tasarımı, fen öğretmenlerinin ve öğretmen adaylarının TPAB gelişimlerini desteklemek için hazırlanacak program ve eğitimler için yol gösterici olabilir. Ayrıca, Türkiye'de gerçekleştirilen TPAB araştırmalarında çoğunlukla nicel yöntemler tercih edilmiştir; bu nedenle, ulusal bağlamda TPAB kavramsal çerçevesini detaylı araştırılması için nitel veya karma yöntem izleyen araştırmalara ihtiyaç duyulmaktadır (Baran & Canbazoğlu-Bilici, 2015). Hem lisansüstü düzeydeki, bir kısmı öğretmenlik yapmakta olan katılımcılarla gerçekleştirilmesi bakımından hem de katılımcıların TPAB gelişim ve değişimlerini detaylı bir şekilde açıklaması bakımından bu çalışmanın ulusal alan yazına da katkı sağlayacağı düşünülmektedir.

Teori-Alıştırma-Pratik Ters Tasarımı

Alan yazın taraması sonucunda TPAB geliştirmeye yönelik tasarlanan eğitim programlarında etkili olduğu farklı çalışmalarda ortaya koyulan en yaygın prensipler belirlenmiş ve T-A-P ders tasarımı bu prensipler çerçevesinde kurgulanmıştır. Bu prensipler ve ders tasarımında nasıl ele alındıkları şöyle özetlenebilir:

1. Teorik bir bilgi temeli oluşturmak TPAB gelişimi açısından önemlidir (Baran & Uygun, 2016; Lee & Kim, 2014; Tondeur vd., 2012). Bu nedenle, T-A-P ders tasarımının teori olarak isimlendirilen ilk aşamasında, katılımcılar beş hafta boyunca alan yazındaki önemli makaleleri okumuş, her ders öncesinde bu makalelerle ilgili düşüncelerini ve tartışma sorularını öğrenme yönetim sistemindeki ilgili sayfada paylaşmış ve ders esnasında araştırmacı tarafından hazırlanan sunum rehberliğinde tartışmışlardır. Ayrıca, TPAB kavramsal çerçevesini anlamaya ve tartışmaya yönelik çeşitli sınıf içi etkinlikler hazırlanmış ve uygulanmıştır.

2. Teknoloji destekli ders planı örneklerini incelemek TPAB gelişimini destekler (Baran & Uygun, 2016; Mouza vd., 2014). Bu prensibe uygun olarak, T-A-P ders tasarımının teori aşamasının son haftasında, katılımcılara çeşitli örnek ders planları verilmiş, katılımcılar bu planları inceleyerek sınıf ortamında tartışmışlardır. Ayrıca, dönem boyunca katılımcılar tarafından hazırlanan tüm ders planları öğrenme yönetim sisteminde herkesin erişimine açık halde paylaşılmış, katılımcıların birbirine dönüt vermesi istenmiştir.

3. Çeşitli teknolojik araçların teknoloji haritalama yaklaşımı kullanılarak incelenmesi TPAB gelişimine yardımcı olur (Angeli & Valanides, 2009; 2013). T-A-P ders tasarımının dört hafta süren alıştırma aşaması boyunca katılımcılar hem alana özgü hem alan bağımsız pek çok teknolojik aracı teknoloji haritalama yöntemiyle incelemiştir. Bu aşama boyunca, katılımcılara her hafta bir teknoloji listesi verilmiş, katılımcıların her bir teknolojiyi gruplar halinde incelemesi, her bir aracın eğitim

açısından güçlü yanlarını, sınırlılıklarını ve öğretim süreçlerinde nasıl kullanılabileceğini belirlemesi istenmiştir. Ayrıca, bu aşama süresince katılımcılar kendi belirledikleri bir teknolojik aracı gruplar halinde sunmuş ve örnek bir uygulama göstermiştir.

4. Teknoloji destekli öğrenme materyalleri tasarlamak TPAB gelişimini destekler (Baran & Uygun, 2016; Koehler vd., 2005; Lee & Kim, 2014; Voogt vd., 2016). TPAB gelişimi için en önemli stratejilerden biri öğretmenlerin tasarım süreçlerine aktif olarak dâhil olmasıdır. Bu nedenle, T-A-P ders tasarımı kapsamında katılımcılar dönem boyunca toplam dört tane teknoloji destekli ders planı hazırlamıştır.

5. Teknoloji destekli ders planlarını uygulamak ve bu uygulamayı değerlendirmek TPAB gelişimine yardımcı olur (Baran & Uygun, 2016; Lee & Kim, 2014). Bu prensip doğrultusunda, katılımcılar T-A-P ders tasarımının üçüncü ve son aşaması olan pratik aşaması süresince hazırladıkları teknoloji destekli bir ders planının mikro-öğretimini gerçekleştirmiş ve sonrasında uygulama deneyimleri hakkındaki görüşlerini yazılı olarak bildirmişlerdir.

6. Teknoloji destekli öğretim materyalleri tasarımlarına dönüt verilmesi TPAB gelişimine yardımcı olur (Tondeur vd., 2012; Lee & Kim, 2014). Bu doğrultuda, T-A-P ders tasarımı kapsamında katılımcıların hazırladıkları ders planlarına hem araştırmacı tarafından hem de arkadaşları tarafından yazılı dönütler verilmiştir.

Tüm bu prensipler ışığında, ders içeriği ve etkinlikleri hazırlanmış ve teori, alıştırma ve pratik olmak üzere üç aşamada uygulanmıştır. Teori aşamasının temel amacı katılımcılara teorik bir bilgi temeli oluşturmaktır. Beş hafta süren bu aşamada katılımcılar TPAB kavramsal çerçevesiyle ve fen eğitiminde teknoloji kullanımıyla ilgili çeşitli makaleleri okuyup sınıf ortamında tartışmışlardır. Konuların haftalara göre dağılımı şu şekildedir:

1. Fen eğitiminde teknoloji entegrasyonu
2. TPAB kavramsal çerçevesi
3. TPAB alan yazın taraması: Araştırmalar ne söylüyor?

4. Fen eğitiminde ve fen öğretmenlerinin eğitiminde TPAB uygulamaları
5. Teknoloji destekli fen ders planı örneklerinin incelenmesi

Alıştırma aşamasında katılımcıların çeşitli teknolojik araçları tanıması, kullanması ve bu araçların fen öğretiminde kullanımını tartışması hedeflenmiştir. Dört hafta süren bu aşama boyunca katılımcılar alana özgü ve alan bağımsız teknolojileri öğrenmiş, kullanmış ve fen eğitiminde kullanımını tartışmıştır. Konuların haftalara göre dağılımı şu şekildedir:

1. Simülasyonlar, sanal laboratuvarlar ve eğitsel oyunlar
2. Mobil uygulamalar, Google hizmetleri
3. Sosyal medya araçları, içerik hazırlama ve sunma programları
4. Wiki platformları, tartışma grupları ve işbirlikçi çalışmaya yönelik platformlar

Pratik aşaması ise katılımcıların yeni edindikleri bilgileri uygulamaya dökmelerini sağlamak üzere oluşturulmuştur. Katılımcı sayısına bağlı olarak üç veya dört hafta süren bu aşama boyunca tüm katılımcılar teknoloji destekli bir ders planının mikro öğretimin gerçekleştirmiş, birbirlerinin örnek uygulamalarını gözlemlemiş, dönüt vermiş ve almıştır.

Yöntem

Bu çalışmada tasarım tabanlı araştırma yöntemi kullanılmıştır. Tasarım tabanlı araştırma yöntemi öğrenme ve öğretme süreçlerini etkileyebilecek ve/ya açıklayabilecek yeni teoriler, ürünler ve uygulamalar geliştirmeyi hedefleyen yaklaşımlar bütünü olarak tanımlanabilir (Barab & Squire, 2004).Tasarım tabanlı araştırma yöntemi, araştırmacılar tarafından eğitim araştırmaları çıktılarının gerçek sınıf ortamlarındaki uygulamalar üzerindeki etkisini artırmak amacıyla kullanılmaktadır (Anderson & Shattuck, 2012).

Mühendislerin ürün geliştirme süreçlerine benzer olarak, tasarım tabanlı araştırma yöntemi kapsamında araştırmacılar belirledikleri bir problemin çözümüne yönelik bir tasarım ortaya koyar. Daha sonra bu tasarım uygulanarak etkililiği değerlendirilir.

Yapılan incelemeler sonucunda tasarımın çalışan ve çalışmayan kısımları tespit edilir, gerekli düzenlemeler yapılır ve yeni bir test döngüsüne başlanır (Scott vd., 2020). Tasarım tabanlı araştırma yöntemi genel olarak (1) uygulama öncesi hazırlık, (2) tasarımın uygulanması, ve (3) geriye dönük analiz olmak üzere üç aşamadan oluşur (Gravemeijer & Cobb, 2006. Bu çalışma kapsamında, ilk aşamada ilgili alan yazın taranmış ve fen öğretmenlerinin TPAB gelişimini desteklemeye yönelik Teori-Alıştırma-Pratik isimli bir ders tasarımı hazırlanmıştır. İkinci aşamada, bu tasarım lisansüstü bir ders kapsamında uygulanmış, süreç boyunca tasarımın etkililiğini değerlendirmek amacıyla veriler toplanmıştır. Üçüncü aşamada ise toplanan veriler analiz edilerek ders tasarımında gerekli değişiklikler yapılmıştır. Ayrıca, tipik bir tasarım tabanlı araştırma iki ardışık döngüden oluşur. Bu çalışma da iki ardışık dönem boyunca uygulanmıştır. Döngüler arasında ders tasarımında önemli bir değişiklik yapılmamıştır; katılımcıların görüşlerine, araştırmacının gözlemlerine ve verilerin analizine dayanarak yalnızca alıştırma aşamasında sınıf ortamında tartışılan teknolojilerin sayısı azaltılmış, bazı teknolojik araçlar katılımcıların daha sonra incelemesi için yalnızca link olarak paylaşılmıştır.

Katılımcılar

Çalışmanın katılımcılarını Teknoloji Destekli Fen Öğretimi isimli derse kayıtlı olan ilköğretim fen bilgisi öğretmenliği mezunu lisansüstü düzeydeki öğrenciler oluşturmuştur. Fen öğretimi ile ilgili pedagoji bilgisine ve alan bilgisine sahip olmak çalışmaya katılım için bir önkoşul olduğu için başka bölümlerden mezun olan öğrenciler çalışmaya dâhil edilmemiştir. Çalışmanın ilk döngüsüne üçü öğretmenlik yapmakta olan toplam 7; ikinci döngüsüne ise biri öğretmenlik yapmakta olan toplam 5 yüksek lisans veya doktora düzeyindeki fen eğitimi öğrencisi gönüllü olarak katılmıştır.

Veri Toplama Araçları

Tasarım tabanlı araştırma yöntemi kapsamlı bir veri seti kullanılmasını gerektirmektedir (Gravemeijer & Cobb, 2006). Bu kapsamda her bir araştırma sorusu için çeşitli nitel ve nicel veri toplama araçları kullanılmıştır. Katılımcıların ders tasarımı hakkındaki görüşlerini araştırmak için yazılı geri bildirimler ve görüşmeler kullanılmıştır. Katılımcıların TPAB yeterlik algılarını değerlendirmek için Teknopedagojik Eğitim Yeterlik (TPACK-Deep) Ölçeği (Kabakçı Yurdakul vd., 2012), teknolojik pedagojik alan bilgisi öz yeterlik inanç düzeylerini belirlemek için ise TPAB-ÖyÖ (Canbazoğlu Bilici vd., 2013) kullanılmıştır. Katılımcıların TPAB düzeylerindeki değişimi incelemek için ise ders planları, görüşmeler ve mikro-öğretim uygulamaları kullanılmıştır. Tablo 1'de her bir araştırma sorusu için kullanılan veri toplama araçları ve süreçleri özetlenmiştir.

Tablo 1

Veri Toplama Yöntemleri

Araştırma sorusu	Veri Toplama Araçları	Veri Toplama Zamanı
1	Yazılı geri bildirimler	Haftalık geri bildirimler: Her ders sonunda Genel bildirimler: Dönem sonunda
	Görüşmeler	Dönem sonunda
2	TPACK-Deep ölçeği	Dönem başında ve sonunda
	TPAP-ÖyÖ	Dönem başında ve sonunda
3	Ders planları	İlk ders planı: Dönem başında İkinci ders planı: Teori aşamasının sonunda Üçüncü ders planı Alıştırma aşamasının sonunda Dördüncü ders planı: Pratik aşamasının sonunda
	Görüşmeler	İlk görüşme: Dönem başında İkinci görüşme: Teori aşamasının sonunda Üçüncü görüşme: Alıştırma aşamasının sonunda Dördüncü görüşme: Pratik aşamasının sonunda
	Mikro-öğretim	Pratik aşaması süresince, bir kez

Veri Analizi

Katılımcıların ders tasarımı hakkındaki görüşlerini incelemeyi hedefleyen birinci araştırma sorusu için toplanan yazılı geri bildirimler Braun ve Clarke (2006) tarafından önerilen tematik analiz aşamaları kullanılarak analiz edilmiştir. Bu aşamalar şu şekilde sıralanmıştır: (1) veriyi tanıma; (2) ilk kodları üretme; (3) temaları araştırma; (4) temaları gözden geçirme; (5) temaları tanımlama ve isimlendirme; ve (6) raporu hazırlama.

Katılımcıların TPAB yeterlik algıları ve öz yeterlik inanç düzeylerinde gerçekleşen değişimi araştırmayı hedefleyen ikinci araştırma sorusu için kullanılan TPACK-Deep ve TPAB-ÖyÖ ölçekleri, ölçeği geliştiren araştırmacıların açıklamaları doğrultusunda analiz edilmiştir. Ölçeklerden elde edilen puanlar hesaplandıktan sonra, katılımcıların skorlarında gözlemlenen değişimin istatistiksel olarak anlamlı olup olmadığını belirlemek için Wilcoxon İşaretli Sıralar Testleri yapılmıştır.

Katılımcıların TPAB düzeylerindeki değişimi inceleyen hedefleyen üçüncü araştırma sorusu için toplanan ders planları TPAB Düzeyi Rubriği (Lyublinskaya & Tournaki, 2014) kullanılarak analiz edilmiştir. TPAB düzeyi rubriği, satırlar TPAB bileşenlerini, sütunlar ise TPAB düzeyini ifade edecek şekilde oluşturulmuştur. Her bir ders planı 1 – Kapsamlı anlayış, 2 – Öğrencilerin anlaması, 3 – Öğretim programı, 4 – Öğretim stratejileri olmak üzere dört TPAB bileşeninde fark etme (1), kabullenme (2), uyum sağlama (3), keşfetme (4) ve ilerleme (5) (Niess vd., 2006) düzeylerinden birinde işaretlenmiştir. Katılımcıların her bileşen için skoru işaretlendiği düzeye göre 0 ve 5 arasında değişiklik gösterebilmektedir. Her bileşenin her düzeyi için biri öğretmen davranışlarını diğeri öğrenci davranışlarını veya dijital materyallerin yapısını tanımlayan iki gösterge verilmiştir. Eğer bir plan herhangi bir bileşende bir düzeyin her iki göstergesini de karşılıyorsa tam puan almaktadır. Eğer göstergelerden yalnızca biri karşılanmışsa, buçuklu puan almaktadır. Katılımcıların toplam TPAB düzeyi ise herhangi bir bileşenden elde ettiği en düşük skora göre belirlenmiştir.

Bulgular ve Tartışma

Bu araştırma kapsamında elde edilen bulgular ve bu bulgulardan çıkarılan sonuçlar her bir araştırma sorusu için ilgili başlıklar altında ele alınmıştır.

Katılımcıların T-A-P Ders Tasarımı Hakkındaki Görüşleri

Katılımcıların çevrimiçi forumda yayınladıkları haftalık geri bildirimlerin tümü, dönem sonunda yazılan genel geri bildirimler ve dördüncü görüşmelerin transkriptleri kullanılarak yapılan analizler her iki araştırma döngüsünde de katılımcıların T-A-P ders tasarımını TPAB kavramsal çerçevesini anlama ve TPAB uygulamaları yapma açısından faydalı ve etkili bulduklarını göstermiştir.

Araştırmanın birinci döngüsüne katılan katılımcılar okudukları makalelerin ve bu makalelerle ilgili görüşlerini yazma ve soru hazırlama uygulamalarının TPAP kavramsal çerçevesinin temel kavramlarını ve ilkelerini anlamalarına yardımcı olduğunu ifade etmişlerdir. Makaleleri okumanın yanı sıra sınıfta arkadaşlarıyla tartışmanın da TPAB gelişimi için katılımcılar tarafından çok faydalı bulunduğu görülmüştür. Ayrıca, TPAB kavramsal çerçevesini anlamaya yönelik gerçekleştirilen sınıf içi etkinlikler de katılımcılar tarafından oldukça etkili bulunmuştur.

TPAB uygulamaları yapmaya yönelik gerçekleştirilen etkinlikler de katılımcılar tarafından takdir edilmiş ve TPAB gelişimlerine faydalı oldukları ifade edilmiştir. Katılımcılar, özellikle teknolojik araçların teknoloji haritalama yaklaşımı kullanılarak incelendiği alıştırma aşamasını TPAB gelişimleri açısından oldukça etkili bulmuştur. Mikro-öğretim uygulaması da hem yeni edinilen teorik bilgilerin uygulamaya dökülebilmesi hem de başka örnek uygulamaları gözlemleme şansı sunması açısından oldukça faydalı bulunmuştur.

Birinci araştırma döngüsü sonunda, katılımcıların çoğu T-A-P ders tasarımını faydalı ve anlamlı bulduklarını ifade etmiştir. Bazı katılımcılar ise bir sonraki döngüde aşağıdaki değişikliklerin yapılmasını önermiştir:

- Teori aşamasındaki sınıf içi etkinliklerin artırılması;
- Alıştırma aşamasında incelenen bazı teknolojik araçların teori aşamasında ele alınması;
- Alıştırma aşamasında incelenen teknoloji sayısının azaltılması.

Bu önerilerden teori aşamasındaki sınıf içi etkinlerin artırılması önerisi dönemin ilk dersinin sonunda iki katılımcı tarafından sunulmuştur. İlk hafta yapılan farklı eğitim tanımlarını inceleme, değerlendirme ve kendi eğitim tanımını oluşturma etkinliği sonrasında katılımcılar benzer etkinliklerin her hafta yapılması gerektiğini ifade etmiştir. Araştırmacı bu öneriyi dikkate alarak teori aşaması boyunca her hafta farklı bir sınıf içi etkinlik hazırlamış, bu etkinlikler her iki araştırma döngüsünde de uygulanmıştır.

Bazı teknolojik araçların teori aşamasında ele alınması önerisi iki katılımcı tarafından dönem sonunda yazdıkları genel geri bildirimde ifade edilmiştir. Ancak yapılan görüşmelerde aynı katılımcılar, teknolojik araçları TPAB ile ilgili teorik bilgi kazandıktan sonra incelemenin daha anlamlı olduğunu da belirtmiştir. Ayrıca, diğer katılımcılar da T-A-P ders tasarımı aşamalarının sırasının anlamlı olduğunu ifade etmiş; teknolojileri eleştirel bir biçimde değerlendirebilmek için TPAB kavramsal çerçevesiyle ilgili teorik bilgi sahibi olmanın önemine vurgu yapmıştır. Bu öneriyle ilgili katılımcılar arasında görüş birliği olmadığı için bu öneri uygulamaya koyulmamıştır.

Alıştırma aşamasında incelenen teknolojik araçlarının sayısının azaltılması önerisi üç katılımcı tarafından sunulmuştur. Bu aşamada katılımcılar çok sayıda teknolojik aracı incelemiş, fen eğitimi açısından güçlü yanlarını, sınırlılıklarını ve potansiyel kullanımlarını belirlemeye çalışmıştır. Ancak ders saatlerinin sınırlı olması nedeniyle bazı haftalarda bazı teknolojilerin sınıfta tartışılmasına vakit kalmamıştır. Bu nedenle, ikinci uygulama döngüsünden önce bazı teknolojiler sınıf tartışmalarından çıkarılmıştır. Her hafta incelemek üzere sunulan teknoloji listeleri değiştirilmemiştir;

ancak araştırmanın ikinci döngüsünde kimi teknolojiler sınıfta incelenmemiş ve tartışılmamış, sadece isteyen katılımcıların kendi boş vakitlerinde incelemeleri için katılımcılarla paylaşılmıştır.

Araştırmanın ikinci döngüsünde yer alan katılımcılar da hem okumak üzere seçilen makaleleri hem de bu makalelerin sınıfta tartışılmasının TPAB gelişimleri açısından oldukça faydalı olduğunu ifade etmiştir. Özellikle katılımcılar tarafından ders öncesinde çevrimiçi forumda paylaşılan tartışma sorularının sunumlara dahil edilmesi ve sınıfça tartışılması katılımcılar tarafından etkili bulunmuştur. Bunun yanı sıra, TPAB bileşenlerinin tanımlanması ve etkili teknoloji entegrasyonu için gerekli fen öğretmeni yeterliklerinin delphi çalışması yoluyla belirlenmesi gibi sınıf içi etkinlikler de katılımcılar tarafından TPAB gelişimleri için faydalı bulunmuştur. TPAB uygulamaları yapmaya yönelik ders etkinlikleri de katılımcılar tarafından takdir edilmiş, teorik olarak edindikleri bilgilerin uygulamaya dökülmesinin TPAB gelişimleri için oldukça etkili olduğu ifade edilmiştir.

İkinci araştırma döngüsünün sonunda katılımcılar tarafından ders tasarımına ilişkin olumsuz geri bildirimler alınmamıştır. Tüm katılımcılar T-A-P ders tasarımını ve aşamalarını, bu aşamalar için hazırlanan etkinlikleri TPAB gelişimini destekleme bakımdan etkili bulduğunu ifade etmiştir. Sonraki dönemler için herhangi bir değişiklik önerisi gelmemiştir.

İkinci araştırma döngüsünün sonunda hem katılımcıların görüşleri hem de TPAB ölçekleri, ders planları, ve görüşmeler yoluyla toplanan verilerin ışığında T-A-P ders tasarımının katılımcıların fen öğretimine yönelik TPAB düzeylerini artırmada etkili olduğu sonucuna varılmış ve çalışma sonlandırılmıştır.

Katılımcıların T-A-P ders tasarımı hakkındaki görüşlerine ilişkin bulgular, tasarımın geliştirilmesinde kullanılan prensipler açısından değerlendirildiğinde tüm prensiplerin ve bu prensiplere ilişkin uygulamaların katılımcıların TPAB gelişimi açısından etkili olduğu sonucuna varılmıştır. Alan yazında önerildiği üzere (Baran & Uygun, 2016; Lee & Kim, 2014; Tondeur vd., 2012). TPAB kavramsal çerçevesi ve fen eğitiminde teknoloji entegrasyonu hakkında teorik bir bilgi temeli oluşturmak katılımcılar tarafından da etkili bulunmuştur. Katılımcıların geri bildirimlerinde etkili teknoloji entegrasyonunu anlayabilmek ve sunulan teknolojileri bilinçli bir şekilde inceleyebilmek için teorik bilgiye sahip olmanın önemi vurgulanmıştır.

Benzer şekilde, teknoloji destekli fen ders planı örneklerini incelemek katılımcıların TPAB gelişimi açısından faydalı bulunmuştur. Teknoloji destekli öğrenme materyali örneklerinin incelenmesi, belirli bir konuyu öğretmek için teknolojinin belirli öğretim yöntemleriyle nasıl birleştirilebileceğini inceleme şansı vermesi bakımından öğretmenlerin TPAB gelişimini desteklemek için önerilmiştir (Baran ve Uygun, 2016; Mouza vd., 2014). Bu çalışmanın bulguları da bu görüşü desteklemiştir.

Angeli ve Valanides (2009; 2013), TPAB gelişimini desteklemek için teknolojileri araştırırken teknoloji haritalama yaklaşımının kullanılmasını önermiştir. Katılımcılar geri bildirimlerinde, teknolojik araçların sunduğu eğitsel olanakları, sahip olduğu sınırlılıkları ve fen eğitimindeki potansiyel kullanımlarını tartışmanın TPAB gelişimleri açısından etkili olduğunu belirtmiştir. Katılımcılar ayrıca, teknolojileri kendi başlarına incelemenin, onları doğrudan öğretim yoluyla öğrenmekten daha etkili olduğunu ifade etmiştir. Katılımcıların tamamına yakını farklı teknolojilerin incelenmesinin teknolojik bilgilerini artırdığını bildirmiştir. Daha önceki çalışmalarda da, teknoloji haritalama yaklaşımının öğretmenlerin alan, pedagoji ve teknoloji bilgilerini anlamlı bir şekilde birleştirmelerine yardımcı olduğu ortaya koyulmuştur (Angeli & Valanides, 2013).

TPAB gelişimini destekleme ile ilgili yapılan çalışmaların büyük çoğunluğunda teknoloji destekli öğrenme materyalleri tasarlamanın TPAB gelişimini desteklediği iddia edilmiştir. Bu çalışmadaki katılımcılar, ders planı hazırlamayı bir ders etkinliğinden ziyade ödev olarak değerlendirdiği için dersle ilgili yazdıkları haftalık geri bildirimlerde bu uygulamanın etkililiğine dair herhangi bir yorumda bulunmamıştır. Ancak son görüşmede ders kapsamında hazırlanan ders planlarının sayısıyla ilgili yorum yapmaları istendiğinde, tüm katılımcılar ders planı hazırlamanın TPAB gelişimleri açısından çok etkili olduğunu söyleyerek, hazırlanan plan sayısının azaltılmaması gerektiğini bildirmiştir. Alan yazındaki benzer çalışmalarda da tasarım odaklı etkinliklerin TPAB gelişimini desteklediği ortaya koyulmuştur (Baran & Uygun, 2016; Koehler vd., 2005; Lee & Kim, 2014; Voogt vd., 2016).

Benzer şekilde teknoloji destekli ders planlarının mikro-öğretim yoluyla uygulanması, öğretmenlere teknoloji kullanarak öğretim yapma konusundaki güçlü ve zayıf yanlarını belirleme ve kendi performanslarını değerlendirme şansı vermesi bakımından TPAB gelişimini desteklemektedir (Baran & Uygun, 2016; Lee & Kim, 2014). Bu çalışmaya katılan yüksek lisans ve doktora düzeyindeki fen eğitimi öğrencileri de mikro-öğretim uygulamasını TPAB gelişimleri açısından faydalı bulduklarını ifade etmiştir.

Son olarak, alan yazına göre teknoloji destekli öğretim materyalleri tasarlamanın ve uygulamanın yanı sıra bu tasarımlara ve uygulamalara dönüt almak da öğretmenlerin TPAB gelişimini desteklemektedir (Angeli & Valanides, 2009; Tondeur vd., 2012; Lee & Kim, 2014). Bu çalışmanın katılımcıları öğretim üyeleri veya arkadaşlarından dönüt almakla ilgili bir yorumda bulunmamıştır. Bunun sebebi, hazırladıkları öğretim materyallerine dönüt almanın öğrenim gördükleri üniversite için yaygın bir uygulama olması olabilir. Bu uygulamayı, T-A-P ders tasarımının bir parçası olarak değerlendirmemiş, zaten hali hazırda devam eden bir uygulama olarak görmüş olabilirler. Öte yandan mikro-öğretim sonunda dönüt almakla ilgili bazı katılımcılar olumlu yorumlarda bulunmuş, bu dönütlerin onların sonraki ders planları açısından faydalı olduğunu ifade etmiştir.

Sonuç olarak, alan yazında da önerildiği üzere TPAB gelişimini yalnızca bazı bileşenlerine odaklanmak yerine bir bütün olarak ele alan dersler, öğretmenlerin TPAB gelişimine yardımcı olmaktadır (Chai vd., 2010; Lyublinskaya & Tournaki, 2014). Dönüşümcü TPAB modelini benimseyen ve bu modele uygun prensipler ekseninde hazırlanan T-A-P ders tasarımı da katılımcılar tarafından TPAB gelişimini destekleme açısından etkili bulunmuştur.

Katılımcıların TPAB Yeterlik Algıları ve Öz Yeterlik İnanç Düzeylerindeki Değişim

Katılımcıların TPAB yeterlik algıları, TPAB yeterliğini *Tasarım, Uygulama, Etik* ve *Uzmanlaşma* olmak üzere dört alt boyutta değerlendiren TPACK-Deep ölçeği (Kabakçı-Yurdakul vd., 2012) ile ölçülmüştür. Ölçek dönem başında ve sonunda olmak üzere iki kez uygulanmış, değişimin istatistiksel olarak anlamlı olup olmadığını değerlendirebilmek için Wilcoxon İşaretli Sıralar Testi yapılmıştır. Her iki uygulama döngüsünde de katılımcıların ölçeğin genelinde ve alt boyutlarında elde ettiği skorlardaki artış istatistiksel olarak anlamlıdır ve etki büyüklüğü yüksek olarak hesaplanmıştır.

Ölçeği geliştiren araştırmacılar, ölçekten edilen toplam puanın TPAB yeterlik düzeyini belirlemede kullanılabileceğini ifade etmiştir (Kabakçı-Yurdakul vd., 2012). Ölçekten elde edilebilen minimum skor 33, maksimum skor 165’tir. Buna göre, 95 ve altındaki puanlar düşük düzeye, 96 ve 130 arasındaki puanlar orta düzeye, 131 ve üzerindeki puanlar ise yüksek düzeye karşılık gelmektedir. Katılımcıların toplam puanlarındaki değişim incelendiğinde, ilk uygulama döngüsünün sonunda 1 katılımcının TPAB yeterlik düzeyi düşükten yükseğe, 4 katılımcının TPAB düzeyi de ortadan yüksek düzeye ulaşmıştır. Döneme zaten yüksek düzeyde başlayan iki katılımcının ise toplam puanları artış göstermiş, düzeyleri değişmemiştir. İkinci uygulama döngüsüne 4 katılımcı yüksek düzeyde 1 katılımcı ise orta düzeyde başlamıştır. Dönem sonunda tüm katılımcıların toplam puanları artış göstermiş ve hepsi yüksek düzeye ulaşmıştır.

Alan yazındaki araştırmalar TPAB yeterlik algısının bağlamsal faktörlerin yanı sıra kişisel faktörlerden de kaynaklanabileceğini iddia etmektedir (Wang & Zhao, 2021). Bu çalışmada da, benzer eğitim geçmişlerine sahip katılımcılar derse farklı TPAB düzeylerinde başlamışlardır. Bu durum çeşitli kişisel faktörlerden kaynaklanıyor olabilir. Ayrıca, TPAB yeterlik düzeyi etkili eğitim uygulamaları ve programlarıyla artırılabilmektedir (Ersoy vd., 2016). Bu çalışmada tüm katılımcıların algılanan TPAB yeterlikleri dersi aldıktan sonra artmış, bu durum da T-A-P ders tasarımının yüksek lisans ve doktora düzeyindeki fen eğitimi öğrencilerinin TPAB yeterliklerini geliştirmede etkili olduğu iddiasını desteklemiştir.

Katılımcıların TPAB öz yeterlik inanç düzeyleri TPAB-ÖyÖ (Canbazoğlu Bilici vd., 2013) ile değerlendirilmiştir. Teknolojik bilgi (TB), pedagojik bilgi (PB), alan bilgisi (AB), teknolojik pedagojik bilgi (TPB), teknolojik alan bilgisi (TAB), pedagojik alan bilgisi (PAB), teknolojik pedagojik alan bilgisi (TPAB) ve bağlam bilgisi (BB) olmak üzere sekiz alt boyuttan oluşan ölçeğin maddeleri 10'lu likert tipindedir. Katılımcıların her bir maddeye "Yapabileceğime kesinlikle inanmıyorum: 0" ve " Yapabileceğime kesinlikle inanıyorum: 100" kriterlerine göre 0 ve 100 arasında bir puan vermeleri istenmektedir (Canbazoğlu Bilici vd., 2013). Ölçek dönem başında ve sonunda olmak üzere iki kez uygulanmış, değişimin istatistiksel olarak anlamlı olup olmadığını değerlendirebilmek için Wilcoxon İşaretli Sıralar Testi yapılmıştır.

İlk uygulama döngüsünde katılımcıların TPAB-ÖyÖ'den elde ettiği puanlardaki artış tüm alt boyutlarda ve ölçeğin genelinde istatistiksel olarak anlamlı bulunmuştur ve etki büyüklüğü yüksek olarak hesaplanmıştır. İkinci uygulama döngüsünde ise katılımcıların puanlarındaki değişim hiçbir alt boyutta istatistiksel olarak anlamlı değildir. Bu durumun nedenini araştırmak adına katılımcıların bireysel puanları incelendiğinde, bir katılımcının (Birhan) ön-test puanlarının çok yüksek olduğu, alt boyutlar ve toplam ölçek puanı için 96 ve 100 arasında değiştiği görülmüştür. Her ne kadar aynı katılımcının son-test puanları da oldukça yüksek olsa da ve alt boyutlar ve toplam ölçek puanı için 88 ve 96 arasında değişse de örneklem sayısının küçük olması nedeniyle bu düşüş sonuçların istatistiksel olarak anlamlı olmasını engellemiştir. Bu düşüşün sebebi katılımcının ders süresince etkili teknoloji entegrasyonuna yönelik bilgi ve farkındalığının artmasıyla açıklanabilir. Ön-testte daha yüzeysel bir bilgiyle teknolojiyi çok etkili kullanabileceğini düşünen katılımcı, ders sonunda kendi yeterliklerini daha bilinçli ve eleştirel bir bakış açısıyla değerlendirmiş olabilir.

Alan yazında da belirtildiği üzere, teknoloji destekli öğretim materyali tasarlama etkinlikleri (Yerdelen-Damar vd., 2017) ve direkt olarak TPAB gelişimini desteklemeye yönelik hazırlanan etkinlikler sayesinde TPAB öz yeterlik inancı artırılabilir. Bu çalışma da, T-A-P ders tasarımının ve bu modele göre hazırlanan etkinliklerin Birhan hariç tüm katılımcıların TPAB öz yeterlik inanç düzeylerini artırmada etkili olduğu görülmüştür.

Katılımcıların TPAB Düzeylerindeki Değişim

Katılımcıların TPAB düzeyindeki değişim dönem boyunca dört kez toplanan teknoloji destekli ders planlarının Lyublinskaya ve Tournaki (2012; 2014) tarafından geliştirilen rubrik kullanılarak değerlendirilmesiyle incelenmiştir. Katılımcılar ilki dönem başında, ikincisi teori aşamasından sonra, üçüncüsü alıştırma aşamasından sonra ve dördüncüsü ise pratik aşamasından sonra, yani dönem sonunda olmak üzere toplam dört ders planı hazırlamıştır. Bu ders planları için katılımcılara bir ders planı şablonu verilmiş, bu şablonda katılımcıların hem öğretim sürecini detaylı bir şekilde açıklamaları hem de seçtikleri teknoloji, konu ve öğretim yöntemine dair açıklamalar yapmaları istenmiştir. Katılımcılara konu, öğretim yöntemi veya teknoloji seçimine dair herhangi bir sınırlama getirilmemiş, ulusal fen öğretimi programına bağlı kaldıkları sürece istedikleri seçimleri yapabilecekleri bildirilmiştir. Her bir ders planı *1 – Kapsamlı anlayış, 2 – Öğrenci öğrenmesi, 3 – Öğretim programı, 4 – Öğretim stratejileri* olmak üzere dört TPAB bileşeninde *fark etme (1), kabullenme (2), uyum sağlama (3), keşfetme (4) ve ilerleme (5)* (Niess vd., 2006) düzeylerinden birinde işaretlenmiştir.

Katılımcıların dönem başında hazırladıkları ders planları incelendiğinde, iki uygulama döngüsünde de katılımcıların çoğunun fark etme ve uyum düzeylerinde olduğu görülmüştür. Bu düzeylerdeki öğretmenler genellikle öğretmen merkezli pedagojik stratejiler kullanır ve teknolojiyi motivasyon, pratik yapma ve/veya öğretmen gösterimleri için kullanır. Bu seviyelerdeki öğretmenlerin bilgisi, teknoloji, içerik ve pedagoji için farklı bilgi yapılarından oluşur. Öğretmenler, ayrı yapılar halinde sahip oldukları teknoloji, alan ve pedagoji bilgilerini TPAB'a dönüştürmek için belirli bir konuyu teknoloji ile öğretme ve öğrencilerin konuyu teknoloji yardımıyla keşfetmelerini destekleyebilmek için etkili pedagojik stratejiler kullanma konularında deneyimlere ihtiyaç duyarlar (Niess, 2013). Daha önceki çalışmalarla tutarlı olarak, bu sonuç katılımcıların lisans eğitimlerinin onları teknoloji destekli fen öğretimine hazırlamadığını göstermiştir (Lyublinskaya ve Tournaki, 2013).

Dönem başında yalnızca birkaç katılımcı uyum sağlama düzeyinde değerlendirilmiştir. Bu düzeydeki öğretmenler teknolojiyi öğretimlerine entegre etmeye çalışırlar; ancak, en iyi ihtimalle, öğretmen merkezli düşük seviyeli etkinlikler hazırlayabilirler (Niess, 2012). Bu seviyedeki öğretmenlerin içerik, pedagoji ve teknoloji bilgilerini TPAB'a dönüştürmeye başladıkları söylenebilir, ancak öğrencilerin öğrenmesini desteklemek ve öğretim uygulamalarını geliştirmek için teknolojiden yararlanabilme noktasında daha fazla tecrübeye ihtiyaç duyarlar.

Dönem başında keşfetme seviyesinde sadece bir katılımcı vardı, Nilgün. İlköğretim bölümünde doktora yapmakta olan Nilgün, argümantasyon tabanlı öğretim alanında çalışmalar yapmaktaydı. Çalışma sırasında aktif olarak öğretmen olarak çalışmıyordu, ancak iki yıllık saha deneyimi vardı. Nilgün'ün hazırladığı ilk ders planı, öğrencileri konuyu keşfetmek için teknolojiyi kendi başlarına kullanmaya teşvik eden argümantasyon etkinlikleri içeriyordu ve başlangıç TPAB düzeyi teknoloji entegrasyonu konusunda daha önceden herhangi bir eğitim almamış olmasına rağmen oldukça yüksekti. Bu sonuç öğretmenlik deneyimi olması ile açıklanamaz zira öğretmenlik deneyimi olan diğer katılımcıların başlangıç TPAB düzeyi daha düşüktü. Argümantasyon tabanlı öğretim ile ilgili çalışmalar yapıyor olması da bu durumu kendi başına açıklayamaz zira benzer bir araştırma deneyimi olan Nazım'ın başlangıçtaki TPAB düzeyi fark etme olarak belirlenmişti. Benzer şekilde aynı lisans programında mezun olan diğer katılımcıların TPAB düzeyleri de Nilgün'e kıyasla daha düşüktü. Bu durum Nilgün'ün bu ders planı için harcadığı kişisel çaba, diğer kişisel özellikleri ve faktörler olabilir.

Katılımcıların başlangıçtaki TPAB düzeyleri, iki uygulama döngüsünde de çoğunun etkili teknoloji entegrasyonu için gerekli bilgi ve becerilere sahip olmadığını ortaya koymuştur. Öğretmenlik tecrübesi çok az olan veya hiç olmayan öğretmenler çoğunlukla teknolojiyi pratik yapma amacıyla kullanmakta ve öğretim süreçlerine entegre etmekte zorlanmaktadır (Agyei & Voogt, 2011; Otenbreit-LeTwich vd., 2010;

Tondeur vd., 2017). Öğretmen adayları ve mesleğe yeni başlayan öğretmenlerin TPAB gelişimleri için özellikle TPAB gelişimi için tasarlanmış etkili uygulamalara ihtiyaçları vardır.

T-A-P ders tasarımının, teorik bir bilgi temeli oluşturmayı hedefleyen teori aşamasının sonunda iki uygulama döngüsünde de katılımcılarının TPAB düzeylerinde çok ciddi bir değişim olmamıştır. İki döngüye katılan toplam 12 katılımcıdan üçünün TPAB düzeyi ilerlemiş, ikisinin TPAB düzeyi gerilemiş ve diğer katılımcıların ise TPAB düzeyinde herhangi bir değişiklik olmamıştır. Buna göre, TPAB kavramsal çerçevesiyle ve fen eğitiminde teknoloji entegrasyonuyla ilgili teorik bilgi sahibi olmanın TPAB gelişimi için tek başına yeterli olmadığı sonucu çıkarılabilir. Alan yazında yalnızca teorik bilgi sahibi olmanın TPAB gelişimine etkisini araştıran başka bir çalışmaya rastlanmamıştır. Ancak teorik bilgi sahibi olmanın önemli olduğunu öne süren araştırmacılar, TPAB gelişimi için teorik bilgi temeli kazandırmayla birlikte başka stratejiler de kullanılmasını önermiştir (Baran & Uygun, 2016; Tondeur vd., 2012). Bu çalışmada da görüldüğü üzere sadece teorik bilgi sahibi olmak TPAB gelişimi için yeterli değildir, TPAB gelişimini desteklemeye yönelik uygulamalarda birden fazla yöntem kullanılmalıdır.

T-A-P ders tasarımının katılımcıların teknoloji bilgisini artırmayı ve çeşitli teknolojik araçların fen eğitiminde nasıl kullanılabileceğiyle ilgili bakış açısı kazandırmayı hedefleyen alıştırma aşamasının sonunda, iki uygulama döngüsünde yer alan toplam 12 katılımcıdan 10'unun TPAB düzeyi ilerlemiş, yalnızca Nilgün ve Ayten bir önceki TPAB düzeylerinde kalmıştır. Nilgün'ün TPAB düzeyi her üç ders planı için de keşfetme olarak belirlenmiştir. Zaten başlangıçtaki TPAB düzeyi çok yüksek olduğu için bu durum normal karşılanabilir. Ayten ise kabullenme düzeyinde kalmış, TPAB düzeyinde bir ilerleme olmamıştır. Hazırladığı üçüncü ders planında bir artırılmış gerçeklik uygulaması yardımıyla elementler konusunun öğretilmesi hedeflenmiş, ancak dersin işlenişinin iyi planlanmadığı tespit edilmiştir. Her ne kadar öğretilmesi hedeflenen konuya uygun bir teknoloji seçilmiş olsa da kullanılan öğretim yönteminin iyi kurgulanamadığı gözlemlenmiştir.

Alıştırma aşamasının sonunda, Ayten hariç tüm katılımcıların TPAB düzeyi uyum sağlama ve keşfetme düzeylerine ilerlemiştir. Uyum sağlama düzeyindeki katılımcılar, teknolojik araçları öğretim süreçlerine çoğunlukla öğretmen merkezli öğretim yöntemleri kullanarak entegre etmiş, öğrencilerin teknolojiyi kullanmasına yönelik etkinlikler planlanmış olsa da bu etkinlikler oldukça yapılandırılmış, çok fazla yönlendirme içeren çalışma kağıtları yardımıyla öğretmen kontrolünde gerçekleştirilmiştir. Özellikle öğretmenlik deneyimi az olan öğretmenler için teknoloji desteli ders planları hazırlarken öğrenci merkezli, sorgulamaya dayalı öğretim yöntemlerini kullanmak zor olabilmektedir (Kaplon-Schilis, 2018; Wang vd., 2008). Öğretmenler hem sorgulama tabanlı öğretim ile ilgili hem de teknoloji destekli öğretim ile ilgili daha fazla deneyime ihtiyaç duymaktadır. Öğretmenlerin yüksek düzeyde TPAB sahibi olabilmek ve teknolojiyi öğretim süreçlerinde kullanabilme özgüveni kazanmak için uzun süreli eğitime ihtiyaçları vardır (Koh & Divaran, 2011). Önceki araştırmalarda da, bazı öğretmenlerin TPAB ile ilgili mesleki gelişim programlarına katıldıktan sonra dahi geleneksel öğretim uygulamalarını sürdürdükleri, teknolojiyi daha düşük seviyedeki etkinlikler için kullandıkları görülmüştür (Lyublinskaya & Tournaki, 2011; Niess vd., 2008).

Keşfetme düzeyine ilerleyen katılımcıların teknolojiyi ders planlarına entegre ederken öğrenci merkezli yöntemler kullandıkları görülmüştür. Uyum sağlama düzeyi ve keşfetme düzeyi arasında öğretmen ve öğrenci rolleri bakımından fark bulunmaktadır. Keşfetme düzeyindeki öğretmenler teknolojik araçları kullanarak öğrenciler için sorgulamaya dayalı fen öğretimi etkinlikleri hazırlayarak, öğrencilerin teknoloji kullanımı süresince yönetici değil rehber olarak görev almayı tercih etmektedir. Öğretmenlik deneyimi ile TPAB düzeyi arasında bir tutarlılık gözlemlenmemiştir; öğretmenlik deneyimi olan dört katılımcının ikisi uyum sağlama düzeyinde ikisi ise keşfetme düzeyinde yer almıştır.

Bu çalışmanın bulguları ışığında, teknoloji haritalama yöntemiyle çeşitli teknolojilerin incelenmesi ve tartışılmasının TPAB gelişimi açısında faydalı olduğu söylenebilir. Teknoloji haritalama yaklaşımında teknolojik araçlar katılımcılara direkt öğretim yoluyla sunulmamakta, her bir aracın eğitsel olanakları, sınırlılıkları ve kullanımları incelenmekte ve tartışılmaktadır. Bu yaklaşımın etkililiğinin değerlendirildiği benzer çalışmalarda da teknoloji haritalamanın TPAB gelişimi açısından faydalı olduğu ortaya koyulmuştur (Angeli & Valanides, 2009; 2013). Yalnızca teknoloji bilgisine odaklanarak teknoloji, pedagoji ve alan bilgisi arasındaki etkileşimleri göz ardı etmek TPAB gelişimi açısından anlamlı değildir. Öğretmenlerin teknolojik araçları aktif bir biçimde kullanması, keşfetmesi ve alana özgü bir bakış açısıyla değerlendirebilmesi gerekmektedir (Tondeur vd., 2012).

T-A-P ders tasarımının son aşaması olan pratik aşamasında tüm katılımcılar hazırladıkları üçüncü ders planlarını kullanarak mikro-öğretim yapmıştır. Bu aşamanın sonunda, iki uygulama döngüsüne katılan toplam 12 katılımcının yarısının TPAB düzeyi ilerlemiş, yarısı ise bir önceki seviyesinde kalmıştır. Bu nedenle, mikro-öğretim uygulamasının TPAB gelişimine tekil etkisi açısından bir sonuca varmak zordur. Alan yazındaki araştırmalar teknoloji destekli ders planlarını uygulamanın TPAB gelişimi açısından etkili olduğunu öne sürmektedir (Baran & Uygun, 2016; Lee & Kim, 2014). Her ne kadar bu araştırmada mikro-öğretimin tekil etkisi tutarlı bir biçimde gözlemlenemese de bu uygulama ve pratik aşaması katılımcılar tarafından oldukça faydalı bulunmuştur.

Pratik aşamasının sonu aynı zamanda ders döneminin de sonuna karşılık gelmektedir. Dönem sonunda iki uygulama döngüsünde yer alan toplam 12 katılımcının yedisi keşfetme düzeyinde, üçü ise uyum sağlama düzeyindedir. Yalnızca iki katılımcı dönem sonunda en yüksek düzey olan ilerleme düzeyine ulaşabilmiştir. Bu düzeydeki öğretmenler öğretilen konuyu geleneksel yöntemlerden farklı bir bakış açısıyla yorumlayarak öğrenciler için teknoloji destekli açık araştırma etkinlikleri hazırlayabilmektedir (Niess, 2011). Öğrenciler teknolojiyi aktif olarak kullanarak kendi öğrenim süreçlerini kendileri kontrol etmekte, teknoloji destekli etkinlikler üst düzey düşünme becerilerini geliştirecek şekilde kurgulanmaktadır (Kaplon-Schilis, 2018; Lyublinskaya & Tournaki, 2014). Tek bir ders dönemi sonunda tüm katılımcıların en yüksek TPAB düzeyine ulaşmasını beklemek gerçekçi değildir; TPAB gelişimi uzun süreli eğitim ve çaba isteyen zorlu bir süreçtir.

Öneriler

Alan yazında da sıklıkla ifade edildiği üzere (Agyei & Voogt, 2011; Bate, 2010; Tondeur vd., 2017), öğretmen yetiştirme programlarından mezun olan öğretmenler etkili teknoloji entegrasyonu için gerekli bilgi ve becerilere sahip değildir. Mesleğe yeni başlayan öğretmenlerin çok azı teknolojiyi öğrenci merkezli öğrenme etkinlikleri içinde etkili bir biçimde kullanabilmektedir (Gao vd., 2011). Bu nedenle, öğretmenlerin gelecekteki sınıflarındaki teknoloji kullanımlarını iyileştirmek için öğretmen programlarının geliştirilmesi gerekmektedir (Chai, Koh, & Tsai, 2010; Göktas vd., 2009).

Bu çalışmada ortaya koyulan T-A-P ders tasarımı, fen bilgisi öğretmenliği mezunu, yüksek lisans veya doktora düzeyindeki fen eğitimi öğrencilerinin TPAB gelişimi açısından faydalı bulunmuştur. Bu çalışmada etkililiği test edilen tasarım prensipleri ve T-A-P ders modeli öğretmenlik programlarındaki derslerin geliştirilmesi için yol gösterici olabilir. Ancak T-A-P ders tasarımı bu haliyle öğretmen adaylarıyla kullanılmak için uygun olmayabilr; teori aşamasında okunan ve tartışılan makaleler gözden geçirilmeli ve öğretmen adaylarına uygun olacak şekilde yeniden düzenlenmelidir. Teorik bilgilerin verildiği makalelere odaklanılarak araştırma makaleleri azaltılabilir.

Fen öğretmenlerine yönelik TPAB eğitimleriyle ilgili daha fazla çalışmaya ihtiyaç bulunmaktadır (Baran vd., 2016). Bu çalışma, fen öğretmenleriyle uygulanabilecek bir ders tasarım modeli sunması açısından alana katkı sağlamaktadır ancak bu tasarımın farklı bağlamlarda test edilmesine ihtiyaç vardır. Ayrıca, bu çalışmanın katılımcıları yüksek lisans veya doktora düzeyindeki fen eğitimi öğrencilerinden oluşmaktadır. Bu da katılımcıların daha yüksek motivasyona sahip olmasına, dolayısıyla sonuçların iyi çıkmış olmasına neden olmuş olabilir. T-A-P ders tasarımının aktif olarak öğretmenlik yapan katılımcılarla da test edilmesi önem taşımaktadır.

Katılımcıların TPAB düzeyindeki değişim farklı ölçülerde gerçekleşmiştir. Önceki araştırmalarda da ortaya koyulduğu üzere öğretmenlerin kişisel inançları ve bağlamsal faktörler TPAB gelişimini etkilemektedir (Tondeur vd., 2017). Pedagojik inançlar, öz yeterlik inancı, öğretmenlik deneyimi gibi faktörler, öğretmenlerin teknoloji entegrayonu uygulamalarını etkilemektedir (Manfra & Hammond, 2006; Ottenbreit-Leftwich vd., 2018). Bu çalışmada, öz yeterlik inancı, TPAB yeterlik algısı, veya öğretmenlik deneyimi ile TPAB gelişimi arasında tutarlı bir ilişki gözlemlenememiştir. Bu nedenle, öğretmen özellikleri ve TPAB gelişimi arasındaki ilişkiyi detaylı bir biçimde inceleyen ve TPAB gelişimini olumsuz etkileyen faktörlerin etkisinin nasıl azaltılabileceğini araştıran çalışmalara ihtiyaç vardır.

T-A-P ders tasarımının en etkili aşaması alıştırma aşaması olarak tespit edilmiştir. Fen öğretiminde kullanılabilecek alana özgü ve alan bağımsız pek çok teknolojik aracın incelendiği ve tartışıldığı bu aşama katılımcıların eksik olan teknoloji bilgilerini geliştirmesi açısından faydalı olmuştur. Ayrıca teknolojilerin direkt öğretim yerine teknoloji haritalama yöntemi ile sunulması katılımcılar tarafından da oldukça etkili bulunmuştur. Teknoloji haritalama yöntemi öğretmen yetiştirme programlarındaki eğitim teknolojileri derslerinin içeriğini geliştirmek için faydalı olabilir. Bu nedenle, bu yöntemin öğretmen adaylarıyla kullanıldığındaki etkisini araştıran çalışmalara ihtiyaç vardır.

T-A-P ders tasarımının içeriği fen bilgisi öğretmenliği programı mezunlarına yönelik hazırlanmıştır. Bu nedenle, başka alanlarda görev yapan öğretmenlerle uygulanabilmesi için revize edilmesi gerekmektedir. Her ne kadar ders içeriği fen eğitimine yönelik hazırlanmış olsa da, T-A-P ders tasarımı aşamaları ve bu aşamaların belirlenmesinde yol gösterici olan prensipler başka alanlara rahatlıkla uyarlanabilir.

J. THESIS PERMISSION FORM / TEZ İZİN FORMU

ENSTİTÜ / INSTITUTE

Fen Bilimleri Enstitüsü / Graduate School of Natural and Applied Sciences ☐

Sosyal Bilimler Enstitüsü / Graduate School of Social Sciences ☒

Uygulamalı Matematik Enstitüsü / Graduate School of Applied Mathematics ☐

Enformatik Enstitüsü / Graduate School of Informatics ☐

Deniz Bilimleri Enstitüsü / Graduate School of Marine Sciences ☐

YAZARIN / AUTHOR

Soyadı / Surname : Çetinkaya Aydın
Adı / Name : Gamze
Bölümü / Department : İlköğretim / Elementary Education

TEZİN ADI / TITLE OF THE THESIS (**İngilizce** / English): Design and Implementation of a Graduate Course for Development of Technological Pedagogical Content Knowledge

TEZİN TÜRÜ / DEGREE**:** **Yüksek Lisans** / Master ☐ **Doktora** / PhD ☒

1. **Tezin tamamı dünya çapında erişime açılacaktır. /** Release the entire work immediately for access worldwide. ☒

2. **Tez iki yıl süreyle erişime kapalı olacaktır.** / Secure the entire work for patent and/or proprietary purposes for a period of **two years. *** ☐

3. **Tez altı ay süreyle erişime kapalı olacaktır.** / Secure the entire work for period of **six months**. * ☐

***** *Enstitü Yönetim Kurulu kararının basılı kopyası tezle birlikte kütüphaneye teslim edilecektir. / A copy of the decision of the Institute Administrative Committee will be delivered to the library together with the printed thesis.*

Yazarın imzası / Signature .... **Tarih** / Date ....