

EXPLORING IN-SERVICE SCIENCE TEACHERS' PROFICIENCY LEVELS
AND NATURE OF INTERACTIONS AMONG COMPONENTS OF
TECHNOLOGICAL PEDAGOGICAL AND CONTENT KNOWLEDGE-
PRACTICAL

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

BY

MURAT BERAT UÇAR

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

FEBRUARY 2024

Approval of the thesis:

**EXPLORING IN-SERVICE SCIENCE TEACHERS' PROFICIENCY LEVELS
AND NATURE OF INTERACTIONS AMONG COMPONENTS OF
TECHNOLOGICAL PEDAGOGICAL AND CONTENT KNOWLEDGE-
PRACTICAL**

submitted by **MURAT BERAT UÇAR** 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 KİRAZCI
Dean
Graduate School of Social Sciences

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

Prof. Dr. Elvan ŞAHİN
Supervisor
Department of Mathematics and Science Education

Examining Committee Members:

Prof. Dr. Jale ÇAKIROĞLU (Head of the Examining Committee)
Middle East Technical University
Department of Mathematics and Science Education

Prof. Dr. Elvan ŞAHİN (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. Sedef CANBAZOĞLU BİLİCİ
Gazi University
Department of Mathematics and Science Education

Assoc. Prof. Dr. Kader BİLİCAN
Kırıkkale University
Department of Elementary 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: Murat Berat UÇAR

Signature:

ABSTRACT

EXPLORING IN-SERVICE SCIENCE TEACHERS' PROFICIENCY LEVELS AND NATURE OF INTERACTIONS AMONG COMPONENTS OF TECHNOLOGICAL PEDAGOGICAL AND CONTENT KNOWLEDGE- PRACTICAL

UÇAR, Murat Berat

Ph.D., The Department of Elementary Education

Supervisor: Prof. Dr. Elvan ŞAHİN

February 2024, 397 pages

This study aimed to explore the proficiency levels and the nature of interplays among Technological Pedagogical and Content Knowledge-Practical (TPACK-P) components of in-service science teachers. While the proficiency levels of teachers were examined in terms of assessment, planning and designing, and enactment dimensions, the interplays among TPACK-P knowledge components focused on the domains of assessments, learners, subject content, curriculum design, and practices in teaching. The study adopted a qualitative multiple case study design, collecting data from four middle school science teachers through interviews and observations of their teaching performances. The results indicated that the experienced teachers demonstrated simple adoption level of TPACK-P proficiency in general but did not reach a high level of seamless technology integration for fostering independent learning and scientific exploration. The study identified variations in proficiency levels of teachers across each dimension, including distinctions in the assessment dimension, a spectrum of proficiencies in the planning and design dimension, and diverse proficiency levels in the enactment dimension. Furthermore, five assertions were

derived from the findings and extracted TPACK-P maps aimed at exploring interactions among TPACK-P components. These assertions can roughly be summarized as influential role of assessment in teaching practices, the uniqueness of TPACK-P map of each teacher, the trend of assessment-focused technology integration, underutilized potential of subject content delivery, and the dynamic nature of TPACK. Eventually, this study offered significant implications for science teachers, policy-makers, program developers, and researchers in science education.

Keywords: TPACK, TPACK map, teacher proficiency, in-service science teacher, force and motion



ÖZ

FEN BİLİMLERİ ÖĞRETMENLERİNİN TEKNOLOJİK PEDAGOJİK ALAN BİLGİSİ-PRATİK BİLEŞENLERİ ARASINDAKİ ETKİLEŞİMLERİN DOĞASININ VE YETERLİLİK DÜZEYLERİNİN KEŞFEDİLMESİ

UÇAR, Murat Berat

Doktora, İlköğretim Bölümü

Tez Yöneticisi: Prof. Dr. Elvan ŞAHİN

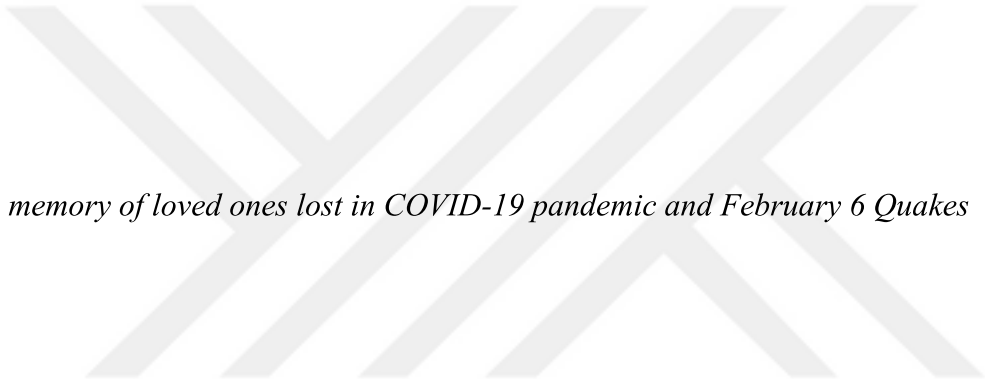
Şubat 2024, 397 sayfa

Bu çalışma, fen bilimleri öğretmenlerinin Teknolojik Pedagojik ve Alan Bilgisi-Pratik (TPAB-P) bileşenleri arasındaki etkileşimlerin doğası ile yeterlilik düzeylerini araştırmayı amaçlamıştır. Öğretmenlerin yeterlilik düzeyleri değerlendirme, planlama ve tasarlama ve uygulama boyutları açısından incelenirken, TPAB-P bilgi bileşenleri arasındaki etkileşimler değerlendirmeler, öğrenenler, konu alanı, program tasarımı ve öğretimdeki uygulamalar bileşenlerine odaklanmıştır. Çalışmada nitel bir çoklu durum çalışması tasarımı benimsenmiş, dört ortaokul fen bilimleri öğretmeninden görüşmeler ve öğretim performanslarının gözlemlenmesi yoluyla veri toplanmıştır. Sonuçlar, deneyimli öğretmenlerin genel olarak basit benimseme düzeyinde TPAB-P yeterliliği gösterdiklerini ancak bağımsız öğrenmeyi ve bilimsel keşfi teşvik etmek için yüksek düzeyde sorunsuz teknoloji entegrasyonuna ulaşamadıklarını göstermiştir. Çalışma, değerlendirme boyutunda farklılıklar, planlama ve tasarım boyutunda bir dizi yeterlilik ve uygulama boyutunda çeşitli yeterlilik seviyeleri de dahil olmak üzere farklı boyutlarda öğretmenlerin yeterlilik seviyelerinde farklılıklar tespit etmiştir. TPAB-P bileşenleri arasındaki etkileşimleri keşfetmeyi amaçlayan bulgulardan ve çıkarılan TPAB-P haritalarından beş sav türetilmiştir. Bu savlar kabaca değerlendirmenin

öğretim uygulamalarındaki etkili rolü, her öğretmenin TPAB-P haritasının benzersizliği, değerlendirme odaklı teknoloji entegrasyonu eğilimi, konu içeriği sunumunun yeterince kullanılmayan potansiyeli ve dinamik TPAB-P doğası olarak özetlenebilir. Sonuç olarak, bu çalışma fen öğretmenleri, politika yapıcılar, program geliştiriciler ve fen eğitimi araştırmacıları için önemli çıkarımlar sunmaktadır.

Anahtar Kelimeler: TPAB, TPAB haritası, öğretmen yeterliliği, fen bilimleri öğretmeni, kuvvet ve enerji





In memory of loved ones lost in COVID-19 pandemic and February 6 Quakes

ACKNOWLEDGMENTS

First and foremost, I would like to express my deepest gratitude to my supervisor, Dr. Elvan Şahin, for her unwavering support, patience, encouragement, and feedback throughout my doctoral education. Her invaluable advice at every stage, particularly during remote times, significantly contributed to the development of my dissertation. I genuinely appreciate her tireless support.

Secondly, I would like to extend my appreciation to the members of my dissertation committee, Dr. Jale Çakıroğlu, Dr. Kader Bilican, Dr. Sedef Canbazoglu Bilici, and Dr. Yezdan Boz for their insightful feedback, suggestion, and expertise. I am thankful for their time, dedication, and commitment to enhancing the scholarly rigor of my work.

Additionally, I'm grateful to colleagues Dr. Eray Şentürk, Dr. Fatih Tıkman, Dr. Bekir Sıddık Kılıç, and Dr. Mehmet Marangoz for sharing their knowledge and fostering a collaborative environment, which greatly contributed to this dissertation. Dr. Eray Şentürk, your enduring support and friendship since my undergraduate years at METU have significantly enhanced my academic journey. Thank you for being an integral part of this meaningful experience.

I would like to express my gratitude to my parents, brothers, and all members of my extended family. Their patience, support, and belief in me made them unsung heroes contributing to the completion of this dissertation. I am thankful that you all never gave up on me and always stood by my side.

A very special thanks go to my beloved wife, Melike, and my cherished son, Bilkan. I am grateful to you for encouraging me to persist in working again during all my stressful and exhausted moments. Your encouragement and unwavering support have been the driving force behind my resilience during challenging times. I am truly fortunate to have such a loving and understanding family by my side.

TABLE OF CONTENTS

PLAGIARISM.....	iii
ABSTRACT	iv
ÖZ	vi
DEDICATION	viii
ACKNOWLEDGMENTS.....	ix
TABLE OF CONTENTS	x
LIST OF TABLES	xiv
LIST OF FIGURES	xv
LIST OF ABBREVIATIONS	xvii
CHAPTERS	
1. INTRODUCTION	1
1.1. Purpose of the Study and the Research Questions	4
1.2. Significance of the Study	5
1.3. Operational Definitions.....	8
2. LITERATURE REVIEW	11
2.1. Conceptual Framework of TPACK	11
2.1.1. The Emergence of TPACK.....	11
2.1.2. The Epistemological Nature of TPACK	13
2.1.3. The TPACK-P Framework	17
2.2. Research on TPACK.....	28
2.2.1. Assessing the TPACK.....	28
2.2.2. Research on TPACK Proficiency	30
2.2.3. Research on Interplay among TPACK Components	37
2.2.4. Research on TPACK Studies related to Force and Energy	

Topics	45
2.3. Summary of the Literature Review.....	47
3. METHODOLOGY	51
3.1. The Philosophical Orientation	51
3.2. Research Design	52
3.3. Selection of the Participants	55
3.3.1. Participant Asaf	59
3.3.2. Participant Bora	59
3.3.3. Participant Cenk.....	60
3.3.4. Participant Esin.....	61
3.4. Selection of the Subject Matter.....	61
3.5. Context of the Study	63
3.6. Data Collection Tools	64
3.6.1. Interviews	64
3.6.2. Observations	66
3.7. Data Analysis	70
3.7.1. Data Analysis for TPACK Proficiency Levels.....	72
3.7.2. Data Analysis for Interactions among TPACK Components	75
3.8. The Pilot Study	79
3.9. Trustworthiness of the Study	81
3.9.1. Credibility	82
3.9.2. Consistency.....	84
3.9.3. Transferability.....	85
3.10. Ethical Considerations	85
4. RESULTS.....	87
4.1. TPACK-P Proficiency Levels of In-service Science Teachers	87
4.1.1. Case 1: Asaf.....	91

4.1.2.	Case 2: Bora	119
4.1.3.	Case 3: Cenk	144
4.1.4.	Case 4: Esin.....	178
4.1.5.	Comparisons and Contrasts in TPACK-P Proficiency Levels Across Teachers	213
4.2.	The Nature of Interplay among TPACK-P Components of In-service Science Teachers	216
4.2.1.	Case 1: Asaf	217
4.2.2.	Case 2: Bora	240
4.2.3.	Case 3: Cenk	261
4.2.4.	Case 4: Esin.....	281
4.2.5.	Comparing TPACK Maps and Formulated Assertions	300
5.	DISCUSSIONS, CONCLUSIONS AND IMPLICATIONS	304
5.1.	TPACK-P Proficiency Levels of In-Service Science Teachers	304
5.2.	Nature of Interactions among TPACK-P Components.....	312
5.2.1.	The prevalence of strong interplays between KoPiT and KoA underscores the critical importance of assessment in influencing teaching practices.....	313
5.2.2.	The distinctive layout of each teacher's TPACK-P map highlights the unique nature of TPACK, emphasizing that no two teachers have the same arrangement of components	315
5.2.3.	The consistent emphasis on assessment across all teachers' TPACK-P maps suggests an overarching trend of assessment- focused technology integration	317
5.2.4.	The limited interplays involving KoSC in teachers' TPACK-P maps point to an underutilized potential for enhancing subject content delivery with ICT	320
5.2.5.	The dynamic nature of TPACK is evident in the variations observed across the teachers' TPACK-P maps, reflecting the	

adaptability of this framework to accommodate individual teaching contexts and preferences	323
5.3. Connecting the dots between TPACK-P proficiency and interplays among the TPACK-P components	326
5.4. Implications of the Study	328
5.4.1. Implications for Science Teachers	329
5.4.2. Implications for Policy-makers and Program Developers	330
5.4.3. Implications for Researchers in Science Teaching	331
5.5. Recommendations of the Study	332
REFERENCES	335
APPENDICES	
A. OBSERVATION PROTOCOL	356
B. THE RUBRIC USED TO ASSESS TPACK-P PROFICIENCY LEVELS	357
C. INTERVIEW PROTOCOL (TURKISH FORM)	360
D. CODING TABLE FOR PROFICIENCY LEVELS	363
E. CODING TABLE FOR INTERPLAYS AMONG TPACK-P COMPONENTS	366
F. APPROVAL OF METU RESEARCH CENTER FOR APPLIED ETHICS	370
G. APPROVAL OF PROVINCIAL DIRECTORATE OF NATIONAL EDUCATION	371
H. INFORMED CONSENT FORM (IN TURKISH)	372
İ. CURRICULUM VITAE	373
J. TURKISH SUMMARY / TÜRKÇE ÖZET	376
K. THESIS PERMISSION FORM / TEZ İZİN FORMU	397

LIST OF TABLES

Table 1. A comparative overview of TPACK-P components in relation to the TPACK framework proposed by Mishra and Koehler (2006).....	27
Table 2. Research design matrix of the study	53
Table 3. The overview of participants' characteristics	58
Table 4. Teachers' focus and activities in observed class sessions.....	69
Table 5. The names and definitions of each interplay.....	76
Table 6. Teacher's TPACK-P proficiency levels according to three educational dimensions and their subdimensions.....	88
Table 7. The proficiency levels of Asaf in assessment	100
Table 8. The proficiency levels of Asaf in planning and designing.....	110
Table 9. The proficiency levels of Asaf in enactment.....	118
Table 10. The proficiency levels of Bora in assessment	126
Table 11. The proficiency levels of Bora in planning and designing	136
Table 12. The proficiency levels of Bora in enactment	144
Table 13. The proficiency levels of Cenk in assessment	154
Table 14. The proficiency levels of Cenk in planning and designing.....	167
Table 15. The proficiency levels of Cenk in enactment.....	178
Table 16. The proficiency levels of Esin in assessment.....	189
Table 17. The proficiency levels of Esin in planning and designing	203
Table 18. The proficiency levels of Esin in enactment	213

LIST OF FIGURES

Figure 1. The TPACK Framework developed by Mishra and Koehler in 2006 and revised TPACK Framework developed by Mishra in 2019	14
Figure 2. Graphical representations transformative TPACK-ICT Model by Angeli and Valanides (2009).....	16
Figure 3. TPACK-Practical Model (Yeh et al., 2014)	18
Figure 4. Selection criteria protocol for participants	56
Figure 5. The classroom layout during observations in each classroom.....	63
Figure 6. Data analysis overview for exploring TPACK-P proficiency levels.....	74
Figure 7. Data analysis overview for exploring the nature of interplay among TPACK-P components	77
Figure 8. A sample TPACK map	78
Figure 9. Image of sample true-false exercise questions used by Asaf on the smart board	97
Figure 10. Representation of the table that Asaf drew on the smart board screen regarding the weight-mass comparison	104
Figure 11. The image of Bora’s markings made with Antropi Teach application on the smart board	122
Figure 12. The image of the animation regarding change of energy and the markings Bora made on the smart board	143
Figure 13. The image of the concept map Cenk used regarding force and energy unit on the smart board	148
Figure 14. List of designs created by the students for the Cenk’s assignment	177
Figure 15. The image of one of the exercise questions Esin opened on the smart board	185

Figure 16. The image of one of the moments of Asaf's virtual experiment demonstrating the relationship between elastic potential energy and displacement	222
Figure 17. Image of close-ended question opened on the smart board by Asaf	229
Figure 18. Asaf's TPACK-P map	239
Figure 19. Representation of the table that Bora drew on the smart board to explain types of variables	246
Figure 20. Bora's TPACK-P map	260
Figure 21. Cenk's TPACK-P map.....	281
Figure 22. Image of matching card game used by Esin on the smart board	283
Figure 23. Esin's TPACK-P map.....	300
Figure 24. TPACK-P maps of each teacher	302

LIST OF ABBREVIATIONS

TPACK	Technological Pedagogical and Content Knowledge
TPACK-P	Technological Pedagogical and Content Knowledge-Practical
KoA	Knowledge of Assessment
KoL	Knowledge of Learners
KoCD	Knowledge of Curriculum Design
KoPiT	Knowledge of Practices in Teaching
KoSC	Knowledge of Subject Content
PK	Pedagogical Knowledge
TK	Technological Knowledge
CK	Content Knowledge
PCK	Pedagogical Content Knowledge
TPK	Technological Pedagogical Knowledge
TCK	Technological Content Knowledge
ICT	Information and Communication Technologies
LMS	Learning Management System
EBA	Educational Informatics Network
MoNE	Turkish Ministry of National Education
FATİH	Movement of Enhancing Opportunities and Improving Technology

CHAPTER 1

INTRODUCTION

In recent decades, societies worldwide have experienced an extraordinary spread in the acquisition and dissemination of knowledge through technology. This rapid transformation has prompted educators and policymakers to reevaluate the ways in which their societies adapt to this shifting landscape. In response, as depicted by Jhurree (2005), the focus of educators has shifted toward preparing students to effectively use the power of technology while also equipping teachers with the skills and knowledge to integrate it smoothly into their teaching practices. This twofold objective depends on the development of teachers' digital competencies which was defined as the "confident, critical, and responsible use of, and engagement with, digital technologies for learning, at work, and for participation in society" (The Council of The European Union, 2018, p. 10).

Integration of technology into education is driven by its potential to enhance comprehension, retention, critical thinking, creativity, and problem-solving skills (Evawati & Susilowati, 2023; Ismajli et al., 2020; Koh et al., 2015). However, realizing this potential rests on the effective utilization of technology within the classroom (Dilworth et al., 2012). Consequently, there is a growing emphasis on equipping teachers with the knowledge and skills needed to seamlessly incorporate technology tools and applications into their teaching practices. This has prompted initiatives to strengthen the technological infrastructure in educational institutions, such as one-to-one computing programs, to ensure widespread access to the internet and individual computers (Topper & Lancaster, 2013).

As educational stakeholders increasingly emphasize integration of technology into classrooms since the new millennium (Culp et al., 2005), the capacity of teachers in utilizing technology becomes a challenging issue. Exploring this challenge has prompted a search for the interactions between content, pedagogy, and technology.

Scholars (e.g., Graziano et al., 2017; Mishra & Koehler, 2006; Yeh et al., 2014) have highlighted the ongoing challenges of integrating technology into teaching, stating a critical lack of a comprehensive model to define teachers' competency in this regard.

Mishra and Koehler's (2006) response to this challenge was to introduce a Technological Pedagogical Content Knowledge (TPACK) framework, derived from Shulman's Pedagogical Content Knowledge (PCK) model (Shulman, 1986). Shulman's work led to a paradigm shift in teacher education by recognizing the pivotal role of PCK (Carlsen, 1999). However, it has been pointed out that PCK alone was insufficient to seamlessly incorporate technology into teaching (Reiser, 1994). To bridge this gap, Mishra and Koehler integrated a technology dimension into Shulman's PCK model. Accordingly, TPACK can be seen as a dynamic framework, revealing the intricate interactions among content knowledge (CK), technological knowledge (TK), and pedagogical knowledge (PK). It emphasizes that the inclusion of technology in educational practices transcends mere addition; it requires a nuanced understanding of the interplay between content, pedagogy, and technology (Mishra & Koehler, 2006).

The revolutionary potential of TPACK in teacher education is accompanied by an evolving perspective on its applications. The emergence of models like TPACK-Practical (TPACK-P) by Yeh et al. (2014) features the importance of assessing teachers' TPACK within their practical teaching environments. TPACK-P deviates from earlier TPACK studies by focusing on evaluating teachers' proficiency in actual teaching rather than solely discussing the composition of their pedagogical, content, and technological knowledge (Yeh et al., 2015a). This transformative approach highlights the significance of evaluating the TPACK of in-service science teachers using TPACK-P indicators, illustrating proficiency levels and interactions within the TPACK-P framework (Yeh et al., 2015a).

In alignment with global trends, the Turkish Ministry of National Education (MoNE) has actively pursued initiatives to advance technology integration in education. For instance, Project FATİH, initiated in 2012, aims to encourage teachers to integrate educational technology into various aspects of education, highlighting the pivotal role of teacher competency in effectively applying educational technology. Moreover, the Strategic Plans for 2015-2019 (Turkish Ministry of National Education, 2015) outlined

a comprehensive vision to enhance the skills of teachers and students in middle and high schools, emphasizing measures such as improving educational technology infrastructure, developing enriched digital books (z-books), and promoting the use of the Educational Informatics Network (EBA). The subsequent 2019-2023 Strategic Plans (Turkish Ministry of National Education, 2019) underscores the critical role of teacher competency and proficiency in leveraging technology for educational purposes. Recognizing the dynamic nature of technological advancements, the plan emphasizes the necessity for tailored teacher training and development programs to enhance technological skills and knowledge.

Despite national initiatives, science teachers in Türkiye often face challenges in integrating technology due to various factors, including contextual issues and a lack of competence, as highlighted in previous studies (Cavas et al., 2009; Özden, 2007; Taş & Balgalmış, 2016). Recognizing that these challenges may negatively impact teachers' TPACK development, research investigating teachers' TPACK becomes crucial. Existing studies often rely on TPACK self-report-based surveys and do not delve deeply into the instructional practices of teachers and teacher candidates (Akyüz, 2018; Ucar & Sahin, 2018), potentially hindering a comprehensive understanding of the nature of their TPACK. Therefore, there is a need for qualitative studies that explore the nature of TPACK through in-depth examination of practical applications, shifting the focus from self-reported measures to detailed information gathered from actual teaching practices.

Moreover, the absence of a comprehensive understanding of the knowledge and proficiency of science teachers in using technology creates a disconnect between theoretical knowledge and practical implementation, emphasizing the need to bridge this gap (Jen et al., 2016). Recognizing these challenges, the exploration of teachers' technological competencies aligns with the objectives of the FATİH project, which emphasizes successful technology integration in various educational aspects. Building upon this recognition, an in-depth investigation into the structure of TPACK required for effective science instruction using ICT tools can offer valuable insights into the strengths and areas for improvement in teachers' technology integration efforts (Bayyigit Teker, 2019). Additionally, the correct and effective use of technology is intricately linked to teachers' TPACK (Albayrak Sarı et al., 2016), making the

understanding of teachers' TPACK a pivotal step in supporting technology integration in science education and identifying teachers' strengths and weaknesses in this challenging field.

In the broader context of technological integration in education and the evolving challenges faced by science teachers, the significance of force and energy topics emerges. These concepts, characterized by their dynamic nature and essential role in the science program, present promising opportunities for innovative technology-based instructional strategies. Moreover, their potential for seamless integration with technology tools underscores the need to understand science teachers' TPACK. Investigating TPACK within the specific domain of force and energy is not only a response to the ongoing challenges of technology integration but also a crucial step towards unraveling the nuanced interplay between technology and science education. Thus, this exploration contributes valuable insights that enhance effective teaching practices in these specific areas, bridging the gap between theoretical knowledge and practical implementation in the realm of science education.

1.1. Purpose of the Study and the Research Questions

This study aims to achieve two fundamental research objectives related to the concept of TPACK of in-service science teachers. The study endeavors to explore the proficiency levels of in-service science teachers in the context of assessing, planning and designing, and enacting their science teaching, all of which are grounded in the TPACK-P framework proposed by Yeh et al. (2014; 2015a). This examination encompasses a comprehensive evaluation of how teachers integrate technology into different phases of science education, emphasizing the importance of both teaching and technological expertise.

Additionally, this research also aimed to investigate the intricate interactions among the five components of TPACK-P possessed by in-service science teachers according to the context of the TPACK-P framework. These components encompass knowledge of learners, subject content, curriculum design, practical teaching, and assessment. Thus, the research highlights comprehensive understanding of the dynamic interactions between these components as utilized by in-service science teachers. This study addresses the following research questions:

- What are the proficiency levels of in-service science teachers' TPACK-P in teaching force and energy topics?
- What is the nature of the interplay among the five TPACK-P components of in-service science teachers in teaching force and energy topics?

These research questions guide the investigation into the proficiency levels and interactions within the TPACK-P framework, offering insights into science teachers' TPACK as it they pertain to teaching of force and energy topics in middle school classrooms.

1.2. Significance of the Study

In today's fast-evolving world, scientific and technological advancements have become indispensable, especially for science educators. Integration of technology into science education is no longer a choice but a necessity in modern schools (Szymkowiak et al., 2021). Science teachers are expected to possess not only deep knowledge of their subject matter, as emphasized by not only the International Society for Technology in Education (2008) standards and the goals of Turkish Ministry of National Education (2018) but also to exhibit proficiency in their TPACK (Yeh, 2015a).

On one hand, science teachers must equip themselves with the necessary knowledge to effectively convey scientific concepts to their students. On the other hand, the integration of technology into teaching has been associated with increased student achievement (Ahmad & Hamad, 2020), making TPACK proficiency a critical attribute for teachers. As role models for their students, science teachers play a significant role in enhancing the quality of instruction, guiding students to master both science content and the utilization of ICT, and preparing them for the digital era (Tondeur et al, 2023). This emphasizes the urgency of identifying, developing, and contributing to the TPACK proficiencies of teachers and teacher candidates (Koh & Divaharan, 2011; Mandaci Sahin et al., 2013). Therefore, examining and analyzing the complex and dynamic nature of science teachers' TPACK through a focus on their teaching practices can provide valuable insights into TPACK discussions in the existing literature.

This study takes a practical approach to TPACK, aiming to investigate in-service teachers' practical knowledge by examining their both personal opinions and in-class teaching practices. The TPACK framework, originally proposed by Koehler and Mishra (2005), has been instrumental in revealing the intricate interplay among technology, pedagogy, and subject matter for effective technology-integrated teaching. Within this context, investigating how in-service teachers demonstrate their TPACK during science instruction by incorporating suitable technologies and strategies is crucial. Practical knowledge is a central component of TPACK development, influenced by teaching experience, and developed tacitly through a complex interplay of teachers' multiple knowledge and beliefs (Voogt et al., 2016). Observations during classroom instruction are essential to understand this practical knowledge (Yeh et al., 2014; 2015a). Thus, this study has the potential to enrich the theory and teacher education literature by uncovering the interactions and influences of TPACK components through evidence-based indicators of in-service science teachers' TPACK.

Prior research on TPACK has often taken quantitative approaches, such as intervention studies (e.g., Kafyulilo et al., 2015; Lyublinskaya & Tournaki, 2014) or survey studies (e.g., Kiray, 2016; Voogt et al., 2013). While these studies have contributed to the TPACK literature, criticisms have been raised, particularly against survey studies used to measure teachers' TPACK. Individuals may not always be aware of their knowledge, skills, or competences, and self-reported knowledge may reflect increased confidence rather than practical expertise (Lawless & Pellegrino, 2007). As Mishra and Koehler (2006) emphasized, it is more appropriate to assess TPACK through performance-based evaluations rather than self-assessment surveys to quantitatively measure TPACK. Hence, this study collects data from in-service teachers and triangulates it with interviews and observations to provide more robust evidence for the appropriateness, correctness of judgements, and reliability of the results (Fisser et al., 2015; Mouza, 2016). As a result, this approach generates more meaningful data based on teachers' actions, shedding light on the nature of TPACK. Considering the existing literature's call for more research examining TPACK in practice (Yeh et al., 2014) that reveals the intricate dynamics of technology integration within the teaching and learning process, this study contributes to addressing this gap. While prior research has explored the concept of TPACK in various educational contexts, there is a gap in

the literature regarding the practical manifestations and interplay among TPACK-P components, specifically among in-service science teachers (Ay et al., 2015). This study seeks to examine the dynamic and situated nature of science teachers' TPACK-P by investigating how they practically utilize ICT tools during science instruction. By exploring the interactions and influences of TPACK-P components through teachers' actions and self-explanations, this research aims to contribute valuable insights into the practical dimensions of TPACK-P among in-service science teachers.

Previous PCK studies have focused on examining interactions among knowledge components, but TPACK studies have rarely delved into these interactions. This is particularly evident when reviewing the existing literature, where studies on teachers' knowledge dimensions within PCK have been explored (Akın & Uzuntiryaki-Kondakçı, 2018; Aydın & Boz, 2013; Park & Chen, 2012), revealing an aspect yet to be investigated within the realm of TPACK. Most research in this area has concentrated on relationships among knowledge components in Mishra and Koehler's (2006) TPACK framework. However, this study aims to explore interactions among TPACK-P components, presenting a significant opportunity to contribute to the literature by addressing this gap.

Notably, prior research regarding TPACK has often been conducted in generic contexts and has rarely delved into the specific nuances of science teachers' TPACK (Lin et al., 2013). This research seeks to address this gap by focusing on the practical and contextualized TPACK of in-service science teachers. The dynamic and situated nature of TPACK necessitates a deeper understanding of how science teachers efficiently integrate technology into their instruction, particularly within the framework of a transformative TPACK model (TPACK-P) that considers the complexities of science education. Recognizing the transformative potential of TPACK is essential, given the challenges encountered in defining clear boundaries for TPACK constructs in previous research (Valtonen et al., 2020). By exploring and analyzing the complex and dynamic nature of science teachers' TPACK, this study contributes to a more nuanced understanding of the TPACK-P framework, with a specific focus on science teachers' practices. Furthermore, previous studies have aimed to investigate the integration of technology into science instruction, covering various science topics. For example, research has shown that incorporating simulations and

animations can enhance students' learning, achievement, and attitude toward science (Adams, 2010; Jaakkola et al., 2011; Yildirim & Sensoy, 2018). However, teaching force and energy topics presents unique challenges, such as the potential for misconceptions and difficulties in student comprehension of concepts and theories (Megalakaki & Thibaut, 2016; Sullivan et al., 2017). As emphasized by Angeli and Valanides (2009), selecting challenging topics is crucial because teaching with technology becomes more meaningful when addressing subjects that are challenging for both students and teachers. Therefore, given the adoption of a topic-specific TPACK approach in this study, the main focus was on investigating in-service science teachers' TPACK within a seventh-grade learning unit centered around force and energy.

Finally, the significance of this study is closely intertwined with the research questions it seeks to address. As the world rapidly advances in scientific and technological realms, it places science teachers in the lead of a changing environment. The necessity of integrating technology into science education is evident, underpinned by its proven positive impact on student achievement (Turan, 2023). To meet these demands, science teachers must possess deep content knowledge while also demonstrating proficiency in TPACK. This proficiency is not only an educational imperative but also a key factor in equipping students for the digital age. Therefore, this research, by exploring the proficiency levels of in-service science teachers' TPACK-P in the context of teaching force and energy topics. Simultaneously, it delves into the dynamic interplay among the TPACK-P components, offering valuable insights into how these components manifest during the teaching of specific science topics. This direct link between the significance of the study and the research questions underscores its critical relevance and positions it as an essential endeavor in enhancing science education and teacher development.

1.3. Operational Definitions

Technological Pedagogical Content Knowledge (TPACK) represents a dynamic, interactive, and intricate connection between technology, pedagogy, and content knowledge (Koehler et al., 2007). TPACK characterizes the essential knowledge teachers must possess for the successful integration of technology into their

teaching methods (Greene & Jones, 2020).

TPACK-Practical (TPACK-P) is one of TPACK frameworks, characterizes the essential knowledge teachers must possess for the successful integration of technology into their teaching. It can be defined as “the practical knowledge framework that science teachers develop for and from using Information and Communication Technologies (ICTs) to assist their instruction” (Yeh et al., 2015a, p. 87).

Information and Communication Technologies (ICT) can be operationally defined as technological devices, platforms, tools, and media that can be online or offline, and used to access, share, interpret, evaluate, or broadcast information for educational purposes by teachers and/or students.

TPACK Proficiency refers to the level of in-service science teachers’ knowledge of using ICT with appropriate pedagogical strategies in teaching science subject matter during the processes of assessing, planning and designing, and enacting science teaching.

Assessment dimension in determining proficiency level of TPACK-P involves a science teacher’s proficiency in using variety of ICT-based formative assessment practices and his/her capacity to effectively understand and meet students’ diverse learning needs.

Planning and designing dimension in determining proficiency level of TPACK-P evaluates a science teacher’s ability to efficiently plan and organize instructional activities. This encompasses goal setting and the strategic use of ICTs to support teaching and learning, as well as the integration of various ICT representations to enhance science instruction. It also assesses the teacher’s flexibility in using student-centered instructional strategies with ICTs.

Enactment dimension in determining proficiency level of TPACK-P pertains to a science teacher’s proficiency in guiding students through ICT-based science instruction. This includes adeptly managing technical challenges and strategically integrating ICT tools into teaching contexts to enhance the learning environment.

Interplay among the TPACK-P components refers to interactions that occur when at least two of the TPACK-P components intersect or influence one another in the context

of technology-enhanced science teaching. These components include knowledge of assessment (KoA), knowledge of learners (KoL), knowledge of subject content (KoSC), knowledge of curriculum design (KoCD), and knowledge of practices in teaching (KoPiT).

Knowledge of Assessment (KoA) entails teacher's knowledge on utilizing ICTs for assessing students' progress. This encompasses a range of ICT-based assessment methods, including the development of assessments using ICT tools and products, conducting both in-class and out-of-class formative assessments, and comprehending the advantages and disadvantages of technology in the assessment process for science classes.

Knowledge of Learners (KoL) refers to knowledge of using ICT to understand students' learning needs such as learning difficulties, learning preferences, and background knowledge. In general, knowledge of learners mainly focuses on the pre-assessment of students.

Knowledge of Subject Content (KoSC) refers to a teacher's expertise in leveraging ICT to deliver science content, particularly for topics that may pose challenges for student comprehension. This knowledge encompasses the skill of effectively using technology to facilitate understanding of subject matter and the ability to discern and employ the most suitable ICT tools to enhance content delivery.

Knowledge of Curriculum Design (KoCD) involves the capacity to systematically plan, design, and orchestrate instructional strategies for technology-infused science lessons. This knowledge requires a deliberate and strategic selection of appropriate ICT representations, teaching techniques, and learning activities in harmony with the objectives and goals of the science curriculum.

Knowledge of Practices in Teaching (KoPiT) encompasses the teacher's expertise in effectively conducting technology-infused science lessons, which includes dealing with ICT-related challenges, encouraging and guiding students in the use of ICT for learning, and efficiently managing the instructional process with technology.

In-service science teacher refers to teachers actively work and teach as science teacher at middle schools.

CHAPTER 2

LITERATURE REVIEW

In this chapter, the literature review offers a concise overview of existing research related to the study's dual purposes. The first objective involves an exploration of TPACK-P proficiency levels among in-service science teachers, while the second objective delves into examining the intricate interplay among the five components of the TPACK-P framework. As such, brief summaries of prior research in the TPACK field were presented to address essential aspects such as the foundational concepts of TPACK and the TPACK-P framework, approaches for evaluating TPACK, the diverse levels of TPACK proficiency, the interconnections among TPACK components, and a summary encapsulating these discussions.

2.1. Conceptual Framework of TPACK

To grasp the context, this section begins by laying the groundwork with basic concepts. Accordingly, it discusses how TPACK emerged, the epistemological nature of TPACK, and the detailed description of TPACK-P framework.

2.1.1. The Emergence of TPACK

Given the significant pressure on teachers and the increasing demand from students for more personalized, interactive, and mobile learning in the 21st century, educational policymakers, administrators, and even parents expect teachers to use technology in classrooms more than ever (Arora & Friedman, 2009). However, embedding technology into teaching practices arises a question: To what extent do teachers effectively utilize technology in their instructions in the classrooms? Concordantly, attempts to address this question focus on necessity of discovering the relationships among content, pedagogy, and technology. In early years of twenty-first century, some criticisms have been arisen among scholars, claiming that effective integration of technology into instruction remained question marks in minds despite increasing

attempts to use various technology tools in education (Jimoyiannis, 2010; Tondeur et al., 2013). These questions could not be answered clearly, since there was a lack of proposing a model describing teachers' competency to integrate technology with their teaching (Mishra & Koehler, 2006). In this manner, Mishra and Koehler (2006) proposed a framework serving to develop these competencies of teachers. They named this framework as Technological Pedagogical Content Knowledge (TPCK, or TPACK). Actually, TPACK was neither a brand-new model nor unique formation. Although Mishra and Koehler introduced this framework to the literature, its roots were originated from Shulman's PCK in 1986.

Shulman suggested three fundamental domains to examine teachers' knowledge, namely, subject matter content knowledge, curricular knowledge and pedagogical content knowledge. Within this categorization of teachers' knowledge, PCK is the focus component since it is the knowledge that differentiates teachers from subject matter specialists (Grossman, 1990; Shulman, 1987). Accordingly, PCK involves knowledge of presenting analogies, illustrations, demonstrations, examples to convey the knowledge of subject matter to students in a more comprehensive manner. In his following study in 1987, he improved his classification of teachers' knowledge and he defined PCK as "the special amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding" (p.8). According to Shulman (1987), there are seven categories of knowledge base, which refers to collective knowledge for being an effective teacher, as follows: content knowledge, general pedagogical knowledge, curriculum knowledge, pedagogical content knowledge, knowledge of learners and their characteristics, knowledge of educational context, and knowledge of educational ends, purposes, and values.

Although Schulman's work resulted in a paradigm shift in teacher education area (Carlsen, 1999), this framework alone was not sufficient to embedding technology into teaching by teachers (Reiser, 1994). Mishra and Koehler (2006) advocated that the reason of this might be scarcity of model, approach, or theory. Thus, they added a technology dimension to Schulman's PCK model to help solving this issue. As a general description, TPACK could be regarded as a framework indicating complex relationships among students, teachers, content, technologies, practices, and tools. To be more specific, Koehler and Mishra (2009) proposed TPACK as an interplay

between three key components: CK (subject matter that is to be taught), TK (computers, Internet, digital video, etc.), PK (practices, processes, strategies, procedures and methods of teaching and learning). This framework highlights the intricate relationships among these domains, emphasizing the need for teachers to navigate the dynamic interplay for effective teaching with technology. However, they stressed that only using technology in teaching activities may not lead teachers to have effective teaching experience. They expressed this phenomenon as follows:

Good teaching is not simply adding technology to the existing teaching and content domain. Rather, the introduction of technology causes the representation of new concepts and requires developing a sensitivity to the dynamic, transactional relationship between all three components suggested by the TPCK framework (p. 134).

Since many school administrators and instructors may recognize advantages of technology in classroom as a tool that prepare students to technology-driven world or as a tool easing the school management works, TPACK framework becomes significant due to showing interplay among technology, content, and pedagogy in schools. In other words, TPACK framework enables teaching staff to enhance their ability to use technology in their profession (Maor, 2013). According to Mishra and Koehler (2006), teachers should have opportunities to use technology in their teaching processes. For instance, appropriate class designs and teaching strategies prepared in accordance with TPACK framework may enable them to perform their teaching activities better. Therefore, TPACK framework can be very useful in incorporating technology with teaching skills for not only teachers but also preservice teachers as well (Mishra & Koehler, 2006).

2.1.2. The Epistemological Nature of TPACK

Even though there are many models or expanded frameworks of TPACK, the epistemological nature of TPACK has been a matter of discussion in the literature. According to integrative view as, TPACK is inherited by knowledge of its parts (CK, PK, and TK) and their combination (PCK, TCK, and TPK) (Angeli & Valanides, (2009). Integrative view posits, for example, that improving components of TPACK would likely improve TPACK. The Venn diagram (Figure 1) of Mishra and Koehler's TPACK framework (2006) has been projected as integrative view because components of the framework are integrated in the action of teaching. The TPACK framework

includes three distinct and interrelated areas of teaching and totally seven components (Figure 1). When taking a close glance in the TPACK, PK refers to teacher knowledge on methods, techniques, applications, and processes of teaching and learning (Mishra & Koehler, 2006). PK covers knowledge regarding learning, assessment of learning, classroom management, arrangement of classroom environment, communication in classroom.

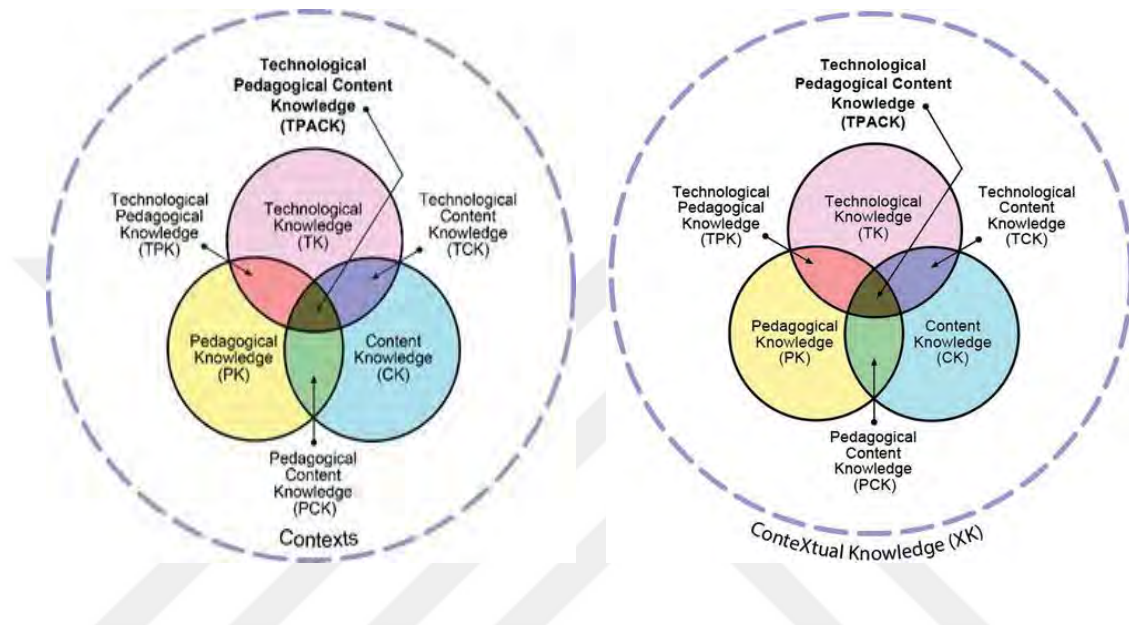


Figure 1. The TPACK Framework developed by Mishra and Koehler in 2006 (on the left) and revised TPACK Framework developed by Mishra in 2019 (on the right)

Second, CK refers to knowledge to be taught in the subject matter. Teachers should have competency to know topics, theories, principles related to their subject matter. In other words, teachers should know what is to be taught in terms of content. Moreover, awareness of teaching methods and subject matter is not enough to teach. Accordingly, Shulman (1986) described PCK as knowledge of selecting suitable teaching methods according to the subject-matter topics. He also argued that transferring of this knowledge to apply during the teaching is also in the context of PCK. In other words, having solely PCK is not important. In addition, applying it in the class is crucial.

The third main component of TPACK is TK. It refers to knowledge of ability to use old and new technologies (Mishra & Koehler, 2006). Therefore, a teacher should know the characteristics and importance of technology that is to be used in the class. In the TPACK framework, the interception of TK and CK constitutes the Technological

Content Knowledge (TCK), which refers to knowledge the ways of transforming the content to represent it with the specific technology in use. Mishra and Koehler (2006) underline that knowing limitations of technologies when integrating it with the related subject matter also indicates the teachers' TCK. Having sufficient TCK will possibly help teachers to evaluate and decide suitable technology tools when they teach their content. On the other hand, it is quite important to know which methods and techniques are best to use technology in teaching processes. Technological Pedagogical Knowledge (TPK) covers the knowledge of which technologies are developed to use in teaching, and the knowledge of using these technologies with necessary pedagogical knowledge (Mishra & Koehler, 2006). In the heart of the TPACK representation, there is TPACK part, indicating not only a sole interception of all remaining knowledge, but also a dynamic, interactive and multifaceted relationship (Koehler et al., 2007). In general, it comprises that knowing of which content topics are present in the technologies that teacher will use, knowing of pedagogical techniques that is applied for teaching of a content topic, knowing how technology can be utilized in order to remove obstacles against student learning (Mishra & Koehler, 2006).

In the original TPACK framework developed in 2006 by Mishra and Koehler, contextual factors were represented by an outer dotted circle surrounding the interlocking circles of TK, PK, and CK. However, this outer circle was not explicitly designated as a form of knowledge. In 2019, Mishra revisited the framework and identified a semantic inconsistency, proposing to rename the outer circle as "Contextual Knowledge" (XK) as depicted in Figure 1. This revision aimed to emphasize that teachers possess knowledge about their context, including awareness of available technologies, understanding of school policies, and familiarity with the broader educational environment. The relabeling of the outer circle as XK highlights its critical role as a variable and dynamic component influencing the success of technology integration efforts within the broader educational context.

On the other hand, transformative view, such as ICT-Related PCK framework illustrated in Figure 2, claims that enhancing knowledge level in any component will not have automatically increase TPACK as asserted in integrative view that fails in explaining technology integration in components of teaching and learning practices

(Angeli & Valanides, 2009; Valanides & Angeli, 2006). Since each knowledge type of TPACK has unique characteristics, TPACK could not be developed automatically by improving other knowledge types (Angeli & Valanides, 2009). Accordingly, the growth in TPACK can be observed only if TPACK training is implemented explicitly toward a whole construct rather than separated bodies of knowledge. As referring to Gess-Newsome' metaphor (1999), integrative model can be thought as mixtures, where the components of mixture still carry out their own characteristics. However, transformative model is like compounds, where components of compound lose their characteristics and carry different characteristics. On the other hand, since knowledge types of TPACK are rooted from three distinct knowledge types and their pairs, theoretical boundaries and meaning are quite complicated (Graham, 2011).

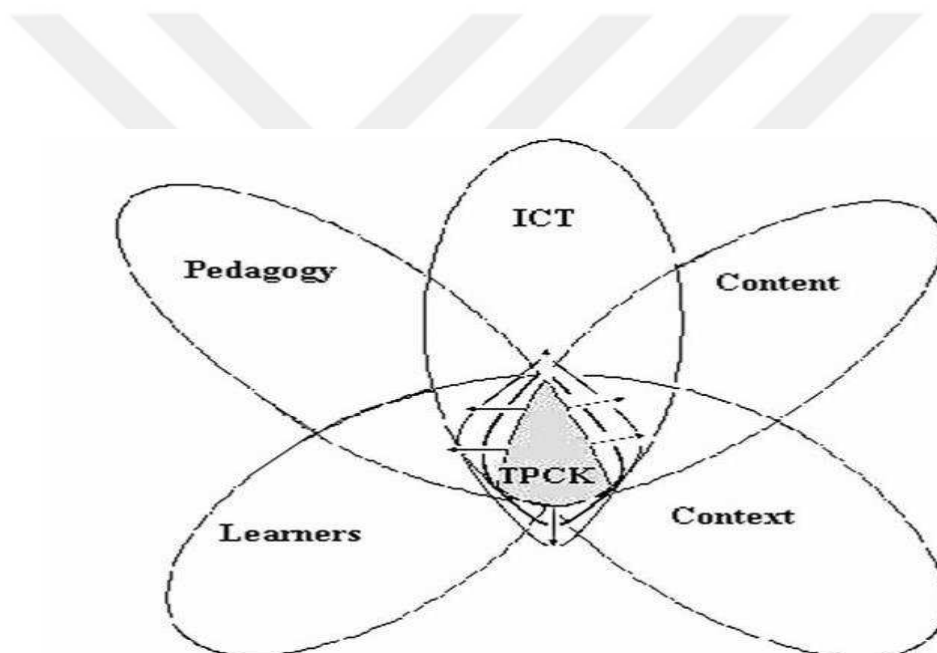


Figure 2. Graphical representations transformative TPACK-ICT Model by Angeli and Valanides (2009)

Previous studies generally adopted three kinds of understandings regarding to TPACK views (Voogt et al., 2013). These views are TPACK as extended PCK (transformative), TPACK as new and distinct type of knowledge (transformative), and TPACK as interplay and intersection of three types of knowledge (integrative). Nonetheless, development of TPACK should not be considered simply as either integration or transformation of different sets of knowledge. TPACK development is strictly bounded with contexts and persons including teacher and students with

authentic experiences (Van Driel et al., 2001).

In the related literature regarding TPACK, there is also a challenging question. That is, scholars wonder whether TPACK is domain-generic knowledge or domain-specific knowledge. In other words, the question is whether teachers who instruct with educational technologies from different domains such as science or math should develop same or different TPACK. Earlier studies recommended that each domain needs specific contextual factors including content, tools, pedagogical strategies in teaching so that each teacher from different domains should possess a specific TPACK body of knowledge (Angeli et al., 2016; Chai et al., 2013). For instance, Jimoyiannis (2010) developed framework for science-specific technological pedagogical content knowledge (TPASK). This framework aims to help science teachers to enhance their professional development through TPASK-based activities and authentic learning in science contents. According to TPASK, science teachers' TPACK differs from other disciplinary experts (i.e., chemist, biologist). In line with Jimoyiannis, domain-specific TPACK approach is likely to contribute to better understanding of generality and specificity of TPACK by considering empirical and qualitative footprints of TPACK in real teaching environment in its specific domain (Angeli et al., 2016).

2.1.3. The TPACK-P Framework

Among transformative TPACK frameworks, Yeh et al. (2014) proposed a framework called TPACK-Practical (TPACK-P), which emphasizes the knowledge-based and practice-based nature of TPACK within specific content. According to them, TPACK-P is a practical knowledge framework including set of knowledge, which science teachers develop for and from using ICTs to assist their instruction. They stated that the elements of the framework were rooted from the framework of Orientation to Science Teaching developed by Magnusson et al. (1999).

The TPACK-P framework is visually represented as a unique body in circles inside a circle, symbolizing inseparable yet interrelated elements (Figure 3). The outward circle encompasses five pedagogical areas, referred to as components in the context of the current study: knowledge of learners, subject content, curriculum design, practical teaching, and assessment. These pedagogical areas house eight knowledge dimensions in the inner circle, each describing ICT use for specific pedagogical purposes. At the

core of the framework is a representation of the transformation of knowledge, highlighting the dynamic interplay among learners, representations, tool affordances, and pedagogy. Unlike integrative TPACK approaches, TPACK-P is formed through the interaction of these elements.

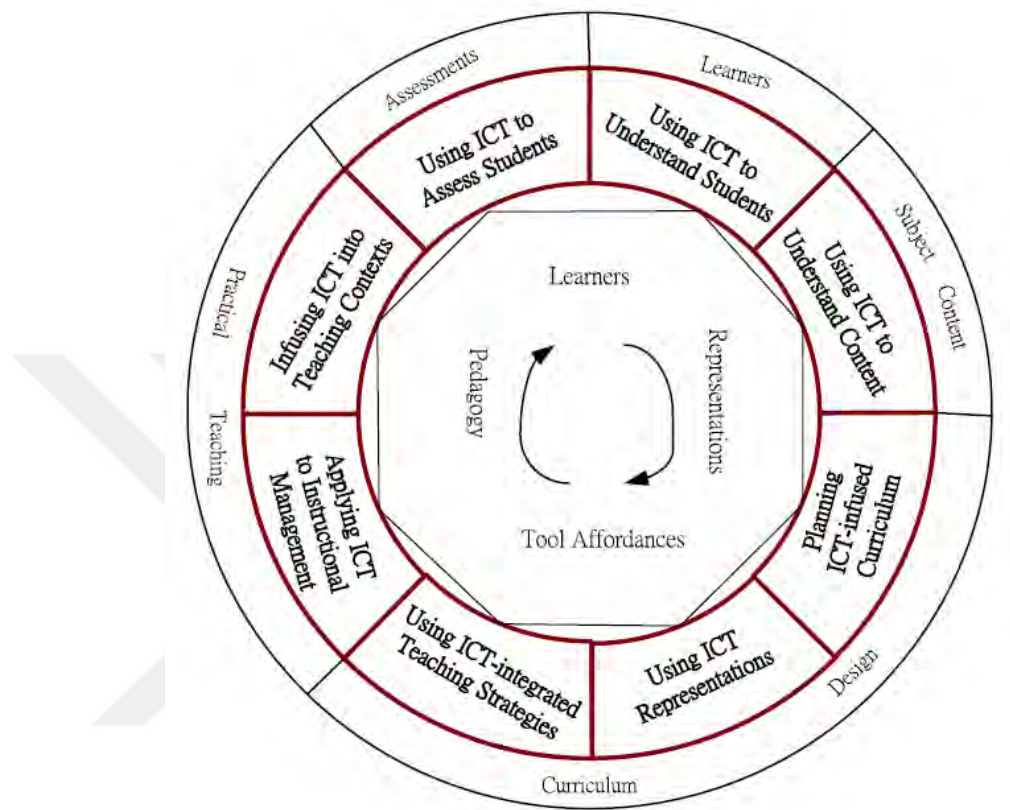


Figure 3. TPACK-Practical Model (Yeh et al., 2014)

The round-shaped framework with inner and outer elements likely signifies the interconnected and holistic nature of TPACK-P. The outer round represents the overarching concept of TPACK-P, emphasizing its comprehensive nature that encompasses various knowledge domains. The inner elements within the outer round could symbolize the specific knowledge dimensions of TPACK-P, each contributing to the overall effectiveness of practical teaching with technology. Moreover, since the circular shape often suggests a cyclical or iterative process, indicating that these elements interact dynamically rather than existing in isolation. This shape conveys the idea that TPACK-P is a continuous and evolving framework, where the interplay among its elements is crucial for successful integration into practical teaching contexts.

The TPACK-P framework, developed by Yeh et al. (2014), resulted from a two-stage

study involving the generation and validation of the model. Six researchers and 54 educators participated in the study, which employed Delphi survey techniques. Initially, potential competencies and knowledge types for effective technology use in teaching were identified, leading to a preliminary framework focusing on five knowledge domains: knowledge of learners, assessment, subject content, planning and design, and practical teaching.

In the second stage, feedback from 54 educators refined the model, resulting in modifications to knowledge dimension names, clearer descriptions, and the amalgamation of some knowledge dimensions. The final TPACK-P framework comprises eight knowledge dimensions under five pedagogical areas: using ICT to understand students, using ICT to understand content, planning ICT-infused curriculum, using ICT representations, using ICT-integrated teaching strategies, applying ICT to instructional management, infusing ICT into teaching contexts, and using ICT to assess students. These dimensions are centrally placed within the framework, underscoring their pivotal role in effective teaching.

Drawing on the perspectives of Van Driel et al. (1998), the TPACK-P framework recognizes the significant roles of teacher application knowledge and PCK in regulating the teaching process and achieving learning objectives through appropriate teaching strategies. Unlike TPACK frameworks focusing solely on knowledge and skills, the TPACK-P framework considers the teaching process as the foundation where application knowledge and TPACK skills synergize. This holistic approach is vital in acknowledging the diverse skills required for different teaching processes, from recognizing students to planning, design, and evaluation.

In proposing the TPACK-P framework, Yeh et al. (2014) acknowledge the significance of teaching experience as an indicator of teacher proficiency in TPACK. The model aligns TPACK not just as a coherent body of knowledge but also as a dynamic entity undergoing rounds of knowledge transformation. Additionally, the findings emphasized the potential of improved ICT applications in teaching management to enhance both student learning progress and the overall integration of technology in teaching.

Each element of the TPACK-P framework is briefly described in the following

subsections.

2.1.3.1. Knowledge of assessment

The element of assessment within the TPACK-P framework, as outlined by Yeh et al. (2014), underscores the importance of teachers possessing specific skills in utilizing ICT for student evaluation. For this, teachers are expected to (1) know the types of technology-infused assessment approaches to understand various technology-centric assessment methods and approaches, (2) identify differences between technology-integrated and traditional assessments, and (3) use ICT to assess students' learning progress.

The contemporary view of assessment, according to the National Research Council (2012), extends beyond conventional summative assessments focused on accountability. It includes formative functions that inform instruction and enhance learning by providing checkpoints and feedback for both teachers and students. In the context of science learning, where students often develop misconceptions and alternative conceptions, the TPACK-P framework recognizes the necessity of preassessment, formative assessment, and postassessment. The assessment component of the TPACK-P framework focuses on both formative assessment and postassessment of students.

Despite the potential benefits of computer-assisted assessments, not all teachers may find them constructive for student learning, and there may be challenges in their implementation. The TPACK-P framework suggests that teachers' proficiency in ICT-infused assessment is crucial. It influences their ability to assess student learning effectively using appropriate ICT tools and strategies, interpret assessment results accurately, and reflect on teaching efficiency.

2.1.3.2. Knowledge of learners

The Learner element within the TPACK-P framework highlights the essential skills teachers need to possess in leveraging ICT to understand and cater to the diverse characteristics of their students. Teachers are expected to (1) know how to use ICT to understand students, (2) know how to use ICT to identify students' learning difficulties, and (3) be able to use different technology-infused instruction for students

with different learning characteristics.

In the process of understanding learners, it is crucial for teachers to analyze learner characteristics such as learning difficulties, learning styles, misconceptions. Teachers draw on their knowledge in the domains of subject matter, pedagogy, and technology to foster optimal learning, creativity, and innovative perspectives in students, whether through face-to-face instruction, virtual environments, or both. As mentioned earlier, the TPACK-P framework recognizes the necessity of preassessment, formative assessment, and postassessment. The learner component of the TPACK-P framework focuses on preassessment of students.

Teachers play a pivotal role in supporting students in developing models, fostering creative thinking, encouraging exploration, providing opportunities to engage with real-world problems, and utilizing digital technological devices and resources in problem-solving. The TPACK-P framework underscores the importance of considering students' cognitive development, cognitive entry behaviors, learning styles, emotional and social development levels, ability to concretize abstract concepts, and learning speed and capacity.

2.1.3.3. Knowledge of subject content

The Subject Content element within the TPACK-P framework focuses on the critical criteria teachers need to fulfill for effective integration of technology in the subject area. Teachers are expected to demonstrate the following skills: (1) be able to use ICT to better understand subject content, (2) be able to identify subject topics that can be better presented with ICT.

According to TPACK-P framework, not every subject area should be presented using random technology. Instead, technology that is going to be utilized must be aligned well with the target subject matter. Teachers need to plan and effectively utilize technologies that are appropriate for the specific subject matter. This involves thoughtful consideration of the characteristics of the subject and selecting technologies that align with the learning objectives.

To maximize the effectiveness of the interaction between subject content and technology Angeli and Valanides (2009) suggest that teachers should identify areas

where students may struggle to grasp concepts or where traditional teaching methods face challenges. These areas might include abstract concepts that benefit from visualization, concepts that require animation, or complex systems with various interacting factors that need systematic modeling. In such cases, teachers should employ presentations that transform the topics into comprehensible structures for learners, utilizing technology to support and enhance understanding.

In summary, the Subject Content element of the TPACK-P framework underscores the importance of teachers' ability to integrate technology effectively into the teaching of subject matter. This involves not only enhancing their own understanding of the subject through ICT but also strategically identifying areas within the subject content where technology can significantly contribute to improved learning outcomes.

2.1.3.4. Knowledge of curriculum design

The Curriculum Design element within the TPACK-P framework involves key competencies that teachers need to develop for effective integration of technology into the curriculum planning and design process. These are related to planning curriculum, representations, and teaching strategies.

In terms of planning ICT-infused curriculum, teachers are expected to demonstrate the following skills: (1) evaluating factors influencing ICT-infused curriculum planning, (2) designing technology-infused lessons or curriculum, and (3) identifying types of technology-infused curriculum designs.

The process of planning and designing curriculum for ICT-infused learning experiences is crucial for teachers as they prepare for upcoming teaching practices. This involves considerations of pedagogy, content, student assessment results, professional learning, and prior experiences to align with students' needs within the intended outcomes (Sherin & Drake, 2009). Transforming and infusing technology into curriculum plans requires knowledge of ICT affordances (Angeli & Valanides, 2009).

In terms of using ICT representations to present instructional representations, teachers are expected to demonstrate the following skills: (1) selecting appropriate ICT representations, and (2) using ICT representations to present instructional content.

In the design process, teachers need to determine how content will be created, what activities will be undertaken to achieve learning goals, and which technologies will be employed. This process varies based on content, learner group, teacher competencies, and available infrastructure.

In terms of employing ICT-integrated teaching strategies, teachers are expected to demonstrate the following skills: (1) indicating appropriate strategies for ICT-integrated instruction, and (2) applying appropriate teaching strategies in technology-integrated instruction.

Strategies play a crucial role in directing the instructional process, from selecting content to evaluating the learning outcomes. Teachers, according to Yeh et al. (2014), need competence in indicating and applying suitable ICT-integrated teaching strategies, aligning with the objectives of the lesson.

In summary, the Curriculum Design element of the TPACK-P framework highlights the importance of teachers' competencies in planning and designing curriculum, selecting appropriate representations using ICT, and employing effective teaching strategies in technology-integrated instruction. This involves a deep understanding of subject matter, students, and the educational context, coupled with the strategic use of technology to enhance the learning experience.

2.1.3.5. Knowledge of practical teaching

The Practical Teaching element of the TPACK-P framework involves competencies related to the application of ICT in instructional management and teaching contexts. This dimension is crucial for teachers as they navigate the complexities of classroom practices, utilizing technology to enhance instruction. The dimension focuses on instructional management and teaching practices.

In terms of applying ICT to instructional management, teachers are expected to demonstrate the following skills: (1) indicating advantages and disadvantages of ICT on instructional management, and (2) using ICT to facilitate instructional management.

In the context of science teaching, knowledge derived from college studies becomes less useful without practical experiences (Gess-Newsome & Lederman, 1993). ICTs

offer stimuli, representations, and channels that accommodate students with varying cognitive development, engaging them in diverse science inquiry activities. Successful enactment of science ideas into classrooms requires adaptive use of ICTs to accommodate students' learning needs, resolving issues in class and sustaining teachers' confidence (Carlson, 1994). These practical experiences are critical for TPACK-P development but are often lacking in teacher education programs.

In terms of infusing ICT into teaching contexts, teachers are expected to demonstrate the following skills: (1) indicating differences between ICT-infused teaching and traditional teaching contexts, (2) using ICT to facilitate achievement of teaching objectives: proficiency in leveraging ICT to facilitate the achievement of teaching objectives, (3) indicating influences of different ICT on instruction, and (4) indicating substitute plans for technology-infused instruction.

In the practical teaching dimension, teachers engage in instructional management, evaluating the effectiveness of the process and assessing the impact of technology on student learning. Yeh et al. (2014) stress that teachers, in utilizing ICT for instructional management, should possess skills to showcase the advantages and disadvantages of ICT and use ICT to streamline instructional management.

Akay (2013) suggests that in the practical teaching process, teachers must plan the use of technological tools for content delivery, instructional strategy application, and techniques execution. Both teachers and learners should have sufficient knowledge about the technology used, and the implementation should facilitate learning without overwhelming or burdening the learners.

In summary, practical teaching within the TPACK-P framework emphasizes the strategic and effective use of ICT in instructional management and teaching contexts, necessitating a deep understanding of the advantages and disadvantages of ICT, as well as the ability to adaptively use technology to achieve teaching objectives.

2.1.3.6. Other elements at the core of the TPACK-P framework

In the TPACK-P framework, the center elements including Learners, Pedagogy, Representations, and Tool Affordances, play a central role in shaping teachers' TPACK. Yeh et al.'s work (2014), as well as insights from Angeli and Valanides

(2009), highlight the significance of these elements in achieving effective ICT integration.

First, Yeh et al. (2014) emphasize the importance of *learners* in the center of the TPACK-P framework. Teachers should have a deep understanding of learners' characteristics, including their cognitive development, learning styles, emotional and social development, and abilities to grasp abstract concepts. This knowledge is crucial for tailoring instruction to meet individual needs.

Second, *pedagogy* is a key element situated in the center of TPACK-P. Teachers need to possess pedagogical knowledge, including effective teaching strategies, methods, and approaches. According to Angeli and Valanides (2009), TPACK should be acquired as a unified set of knowledge, demanding transformational

Third, the use of *representations* involves selecting appropriate ways to present instructional content. Teachers should be adept at choosing and utilizing diverse representations such as visualizations, simulations, and models. Angeli and Valanides (2009) suggest that considering how to represent content effectively with ICTs is a crucial aspect of TPACK. This involves translating abstract concepts into meaningful visualizations to enhance students' understanding.

Finally, *tool affordances* refer to understanding the capabilities and limitations of ICT tools. Teachers should not only be aware of the affordances of ICTs but also consider how to teach with the appropriate selection of these tools. This requires a thoughtful consideration of specific content, student characteristics, and the teaching environment. Knowledge of ICT affordances is critical for designing curriculum, aligning it with student needs, and determining effective teaching strategies (Angeli & Valanides, 2009). Moreover, transformation and infusion of technology into teaching plans demand a deep understanding of ICT affordances. This involves aligning technology with curriculum requirements, student needs, and effective teaching strategies. The challenges lie in the need for twenty-first-century teachers to navigate this transformative process (Angeli & Valanides, 2009).

In essence, the center elements in the TPACK-P framework highlight the interconnectedness of learners, pedagogy, representations, and tool affordances.

Teachers need to navigate these elements thoughtfully to harness the full potential of ICT in enhancing the learning and teaching experience. The integrated understanding of these elements forms the foundation for effective technology integration in education.

Exploring how TPACK-P components resonate with those of the original TPACK framework developed by Mishra and Koehler (2006) is essential before delving into TPACK-related research. Given the prevalent trend in TPACK studies to draw inspiration from or associate their work with the initial TPACK framework, highlighting the similarities and potential variations between the TPACK-P framework adopted in the study and the components of the original framework could contribute to a nuanced understanding of the connections among those components. Table 1 below offers a brief exploration of these resemblances. mapping of factors. This involves aligning pedagogical strategies with technology integration to enhance the learning experience. Table 1 presents a concise comparison between TPACK (Mishra & Koehler, 2006) and TPACK-P (Yeh et al., 2014), outlining potential matches and providing rationale for each pairing. It is important to note that these components are interconnected, and the specific boundaries between them can be somewhat flexible. The delineation might vary based on the educational context and the specific technological tools in use. In the TPACK framework, TK is described as foundational and necessary for all components, suggesting that technology knowledge is woven through various facets of TPACK-P. Similarly, CK in TPACK does not directly align with TPACK-P, as CK involves knowledge about the subject matter without explicitly emphasizing technology integration, maintaining a traditional emphasis on the depth of content knowledge. Likewise, PK in the TPACK framework is not explicitly matched in TPACK-P, given its focus on teaching methods, instructional strategies, and effective management without a specific emphasis on technology integration.

On the other hand, TCK appears to align with KoSC in TPACK-P, emphasizing the potential integration of technology to enhance content delivery. TPK in TPACK corresponds to KoPiT in TPACK-P, encapsulating effective technology use in teaching, including addressing challenges, guiding students in technology utilization, and managing overall instructional processes.

Table 1. A comparative overview of TPACK-P components in relation to the TPACK framework proposed by Mishra and Koehler (2006)

Component from TPACK Framework (Mishra & Koehler, 2006)	The most prominent matching component from TPACK-P used in this study	Rationale on how TPACK-P component is overlapped or intersected with the component of TPACK
Pedagogical Knowledge (PK)	Not directly matched in TPACK-P	PK involves knowledge about teaching methods, instructional strategies, effective management of the teaching process, and student assessment in teaching without particularly emphasizing technology integration
Content Knowledge (CK)	Not directly matched in TPACK-P	CK involves knowledge about the actual subject matter to be taught or delivered without particularly emphasizing technology integration
Technology Knowledge (TK)	Not directly matched in TPACK-P	TK is a foundational knowledge necessary for all components in TPACK-P, rather than being matched with a specific component in TPACK-P
Technological Content Knowledge (TCK)	Mainly KoSC	Both involve knowledge of how technology can create new representations for specific content and enhance the delivery of subject matter
Technological Pedagogical Knowledge (TPK)	Mainly KoPiT	TPK and KoPiT closely align in their emphasis on leveraging diverse technologies for effective teaching. This shared focus includes addressing challenges related to technology integration, guiding students in utilizing technology, and managing the overall instructional process
Pedagogical Content Knowledge (PCK)	Not directly matched in TPACK-P	PCK involves the integration of content and pedagogy to develop better teaching practices without particularly emphasizing technology integration although TPACK-P framework was rooted from PCK
Technological Pedagogical Content Knowledge (TPACK)	Combination of KoA, KoL, KoSC, KoCD, KoPiT	TPACK refers to the integration of technology, pedagogy, and content knowledge. TPACK-P covers a comprehensive set of knowledge domains, including assessment learners, subject content, curriculum design, and teaching practices with technology, reflecting the essence of TPACK

However, PCK in TPACK is not explicitly matched in TPACK-P, as PCK integrates content and pedagogy without a specific emphasis on technology. Finally, the TPACK component in Mishra and Koehler's framework is associated with a combination of KoA, KoL, KoSC, KoCD, and KoPiT in TPACK-P. This implies the comprehensive nature of TPACK, showcasing the integration of technology, pedagogy, and content knowledge across various domains within TPACK-P. Thus, while direct matches may not be definitively evident for PK, TK, and CK, there appear to be closer overlaps in TPK, TCK, and TPACK. Understanding these connections and distinctions is particularly valuable for comprehending the interactions and relationships among TPACK components, providing insights that may enhance the understanding of studies specifically examining these interactions within the TPACK framework.

2.2. Research on TPACK

This section delves into the extensive body of research dedicated to TPACK, addressing various dimensions encountered in the TPACK literature. Initially, with a specific focus on assessment, the first subsection illuminates the diverse methodologies employed to evaluate TPACK within the literature. After presenting a few illustrative examples, this subsection provides a concise overview of TPACK assessment methods. Subsequently, aligning with the objectives of the current study, the following subsections offer a comprehensive literature review on research concerning TPACK proficiency and the interplay among TPACK components, as explored in earlier studies.

2.2.1. Assessing the TPACK

This subsection briefly explores the assessment of TPACK within the TPACK literature. Since its inception by Angeli and Valanides (2005) and Mishra and Koehler (2006), the assessment of TPACK has consistently captured the attention of researchers. Scholars have dedicated efforts to validate, adapt, and improve TPACK frameworks across various contexts, frequently employing survey development as a primary methodology. The majority of TPACK measurement surveys functioned as self-assessment tools, chosen for their ability to reach larger sample sizes at a reduced cost (Voogt et al., 2013). For instance, Schmidt et al.'s (2009) comprehensive TPACK survey and Archambault & Barnett's (2010) survey tailored to online teaching, both

early examples, focus on assessing preservice teachers' self-declared TPACK proficiencies, exploring the seven components of the TPACK framework. Additionally, Canbazoğlu-Bilici et al. (2013) designed a TPACK survey specifically concentrated on science content. The prevailing theme in self-assessment surveys revolved around scrutinizing TPACK in the domains of technology, pedagogy, and content. The prospect of developing new surveys tailored to distinct content areas, educational contexts, and technological applications holds promise for enhancing teachers' TPACK.

Despite the prevalence of self-assessment surveys, concerns about their reliability, particularly when used as pretest and posttest instruments in interventional studies, have led scholars to seek alternative tools. Teaching artifacts, interviews, open-ended questionnaires, and observation reports have emerged as additional tools for measuring TPACK (Baran & Canbazoğlu-Bilici, 2015). Performance-based assessments, while time-consuming, are expected to provide valuable insights into preservice teachers' TPACK practices before graduation. Triangulation of different measurement tools has been proposed to enhance the validity of TPACK assessments, addressing concerns about the weaknesses of Likert-type scale items in providing reliable and valid measurements (Koehler et al., 2012). Content analysis and coding protocols are also suggested as useful methods for assessing TPACK, although they present challenges related to subjectivity and bias (Koehler et al., 2007).

Rubrics are employed to assess participants' TPACK levels after TPACK-related lesson/task treatments. Observations such as those conducted by Angeli & Valanides (2009), Bowers and Stephens (2011), and Kramarski & Michalsky (2010), were utilized to rate TPACK levels based on rubrics. Rubrics, particularly those evaluating participant performance, offer a way to assess TPACK in practical environments and situations. This approach aligns with Mishra and Koehler's (2006) emphasis on assessing TPACK through performance-based assessments rather than relying solely on self-assessment surveys for quantitative measurement.

Qualitative methods also play a crucial role in evaluating TPACK. The qualitative literature underscores the usefulness of TPACK as a lens for examining the development of pre-service and in-service teachers, emphasizing the meaningful use

of technology to transform practice (Harris et al., 2010; Hofer & Harris, 2010; Koehler & Mishra, 2009). It proves valuable in teacher education programs, offering pre-service teachers a means to reflect on their planning and practice (Groth et al., 2009; Mouza & Karchmer-Klein, 2013). However, the qualitative nature of TPACK research, coupled with its contextual specificity and the challenge of measuring a construct still in development, makes generalization difficult.

In the realm of qualitative research, interviews, observation tools, and performance-based assessments are instrumental in measuring TPACK. Interviews provide insights into teachers' thought processes and rationales behind instructional decisions, offering a means to triangulate findings. Performance assessments focus on real-world, authentic tasks, such as creating lesson plans and design tasks. Observation tools, including rubrics, enable the documentation of TPACK in practice, addressing the challenges of self-report instruments. Triangulation of these qualitative methods offers a comprehensive understanding of TPACK, acknowledging its complexities and providing valuable insights into teacher knowledge and practice.

2.2.2. Research on TPACK Proficiency

The exploration of teachers' proficiency on TPACK has been a significant focus in TPACK research. This subsection of review delves into a number of studies that investigate TPACK proficiency among in-service and pre-service science teachers, offering insights into their competency levels.

As a distinctive feature among other frameworks, TPACK-P framework helps to discover the TPACK of teachers' teaching activities in practice rather than discussing teacher knowledge composition epistemologically. In other words, it is not useful to measure the knowledge level teachers' pedagogy, content, and technology instead of evaluating their performances in actual teaching. Because teachers construct and transform all the necessary knowledge of pedagogical techniques and strategies with appropriate technology use and content during their teaching, TPACK should not be considered as simply integrating of different components of knowledge. Rather, Yeh et al. (2015a) claimed that it is necessary to estimate proficiency of teachers to determine their TPACK based on their performances in actual teaching as well as their actions and strategies for teaching. Accordingly, they identified science teachers'

TPACK proficiencies as five levels from 0 to 4, which are namely *no idea*, *lack of use*, *simple adoption*, *infusive application*, *reflective application*, respectively, by evaluating teacher TPACK-P proficiencies in terms of assessment, planning and designing, and classroom instruction domains. These proficiency levels vary based on the authentic teaching practices of science teachers into their teaching with ICT implementation. The categorization and characterization of these proficiency levels were derived and validated from the consensus of the opinions of researchers on the basis of data from interviews, microteaching videos, lesson plans, and rubrics collected from both in-service teachers and pre-service teachers (Yeh et al., 2014; Yeh, et al., 2015a; Yeh et al., 2015b).

Moreover, Yeh et al. (2015a) also illustrated some behaviors and views that are typical for each proficiency levels. In this hierarchical structure of proficiency levels, *no idea* level indicates the lack of behavior or lack of any idea about technology. The remaining four levels vary based on the degree of qualified behaviors and views with respect to TPACK-P. For example, the actions or tendency to using ICT tools barely during planning and enacting the science lesson, or having doubts on the use of e-assessments can be described at basic level (*lack of use*) of TPACK-P. In *simple adoption* level, teachers, for instance, know types and features of ICT tools that can be utilized for science instruction, or believe that use of ICT contributes students' success and motivation. At *infusive application* level, teachers can describe and rationalize their assessment with ICT in detail, or indicate how they plan and use ICT tools for their students who were low in academic achievement. The highest level called *reflective application, or student-centered application* (Yeh et al., 2015b), comprises some sophisticated characteristics such as reflective comment on how ICT tools help teachers to understand students' alternative concepts, misconceptions, learning progress, or evaluating their previous experience in designing technology infused lessons and further customization of instructional materials with suitable pedagogical strategies. Then, these behaviors and views were listed as *indicators* for those dimensions. Thus, these indicators became useful in order to use in determining the level of proficiency for the assessment, planning and designing, and enactment domains. In order to validate the TPACK-P framework proposed by Yeh et al. (2014) and determine the proficiency levels for TPACK-P knowledge outlined in Yeh et al. (2015a), Jen et al. (2016) conducted a study using a standardized testing approach. The

research involved analyzing a group comprising 52 senior-level pre-service and 47 in-service science teachers. The results indicated no significant difference in TPACK-P between in-service and pre-service teachers. Despite the expectation that in-service teachers would demonstrate higher TPACK-P application levels, they did not exhibit superior TPACK-P development compared to pre-service teachers. Another noteworthy finding was that participants' knowledge levels were classified at level 2 and 3, but their practical applications were restricted to level 1. In simpler terms, participants demonstrated a low proficiency in applying TPACK-P compared to their comprehension of TPACK-P knowledge.

In another similar research, Ramnarain et al. (2021) aimed to assess the TPACK of pre-service science teachers at a South African university, employing the TPACK-P framework in their investigation. Through a quantitative approach, the study collected data from a cohort of 103 pre-service science teachers specializing in Life, Natural, and Physical Sciences during their third or fourth year in a four-year Bachelor of Education program. The results revealed a moderate proficiency level in TPACK-P among the pre-service science teachers, with reflective application identified as the highest level of proficiency. The study emphasizes the significance of science teacher education programs in developing TPACK-P proficiency in pre-service teachers, specifically focusing on the effective integration of ICTs into their teaching practices.

Likewise, Pieters (2018) examined the proficiency levels of prospective science teachers in practical knowledge related to TPACK-P. The research encompassed 103 prospective science teachers from the University of Johannesburg, employing a mixed-methods approach that combined a survey questionnaire with semi-structured interviews. The study classified these prospective science teachers into four proficiency tiers based on their use of ICTs in science education. The results unveiled that a majority, specifically 82.52%, demonstrated a proficiency level 3 in comprehending TPACK-P. Nonetheless, a minority exhibited proficiency levels 1 and 2. Level 1 indicated teachers with a rudimentary understanding of technology due to limited experience, negative perceptions, or a lack of intention to integrate ICTs. Those at level 2 (simple adoption) incorporated ICTs in science teaching but often with teacher-centered approaches or less grounded rationales. Participants at level 3 (infusive application) employed ICTs to facilitate student self-exploration and

independent construction of scientific knowledge. Level 4 (reflective application) denoted the highest proficiency, signifying that science teachers effectively applied their experience-based TPACK to integrate ICTs in aiding students' comprehension of science.

Moreover, Ocak and Baran (2019) investigated indicators of science teachers' TPACK through interviews and video recordings of lessons, involving two elementary science teachers and two physics teachers. The outcomes of the analysis suggested that predominant themes encompassed lesson design, implementation of instructional strategies, classroom management, and assessment. Notably, the key finding highlighted that despite the incorporation of technology in their classrooms, science teachers tended to center their technology integration around teacher-directed approaches.

Additionally, Lin & Hsu (2015) explored the digital competence of 40 in-service science teachers in Taiwan based on the Technological, Pedagogical and Content Knowledge-Practical (TPACK-P) framework. The proficiency level of teachers' digital competencies within the framework was categorized into three groups: technology infusive application, technology transitional, and plan and design emphasis group. Although science teachers generally seem to know how to adopt technologies in teaching within each domain of TPACK-P, it was found that there exist differences in the level of their digital competences. The group emphasizing planning and design in their approach comprises science teachers who exhibit greater proficiency in planning and designing technology-integrated instruction compared to their understanding of assessment and teaching practice domains. The general findings suggest that expertise in planning and designing may constitute a relatively distinct aspect within TPACK-P, contributing independently to science teachers' ability to implement technology-infused teaching.

Other than TPACK-P framework, some studies utilized different framework to assesses teachers' TPACK proficiency. For instance, Saubern et al. (2020) investigated the implications of varying levels of TPACK by illustrating how a partial credit Rasch analysis of data from a TPACK survey tool can be utilized to create a detailed quantitative and qualitative account of increasing TPACK proficiency. The research

utilized a modified version of the TTF TPACK Survey to gather data from 152 practicing Australian teachers, and a partial credit Rasch analysis was conducted on the collected data. The findings indicated that with the augmentation of teachers' TPACK proficiency, there was an enhancement in both declarative and procedural knowledge. Declarative knowledge pertains to factual and conceptual understanding, while procedural knowledge involves the skills required to apply that knowledge. The study also observed that the development of declarative knowledge preceded that of procedural knowledge, suggesting that teachers need a robust comprehension of concepts related to effective technology use before effectively implementing that knowledge in the classroom. Additionally, the research identified various subcomponents of TPACK, such as knowledge of software-related strategies and PCK, as significant contributors to TPACK proficiency.

Studies investigating teachers' performances according to the TPACK-Deep framework also contribute to gaining insights into TPACK proficiency. For instance, Tanrisevdi's (2021) study investigated the TPACK competency of science teachers in a developing province in the Central Anatolia region of Türkiye. The research included 136 participants in the survey study, while four science teachers were selected as cases for the case study segment based on their TPACK knowledge and instructional practices. These cases aimed to offer a more in-depth understanding of the relationship between teachers' TPACK knowledge and instructional practices. The study sought to assess science teachers' TPACK competency levels, considering variables such as gender, experience years, and TPACK indicators, which encompass design, exertion, ethics, and proficiency. Conducted through a two-stage process of survey research and multiple case studies, the study employed an explanatory sequential mixed methodology. The results indicated high TPACK competency levels among science teachers, with no significant differences observed in TPACK levels concerning teachers' gender and experience years. Regarding TPACK-Deep factors, teachers scored highest in the ethics factor and lowest in the proficiency factor. Furthermore, teachers with high TPACK competency demonstrated more TPACK indicators, while those with low competency exhibited fewer indicators. Additionally, the TPACK indicators provided valuable insights into TPACK-Deep factors across different competency levels among participant teachers.

Another study conducted by Kabakci-Yurdakul et al. (2014) identified teachers' TPACK competencies and indicators based on Technopedagogical education. These performance indicators for each competency were also defined as a result of workshop documents, audio and video recordings, and researcher diaries. Within six competency fields, namely designing instruction, implementing instruction, opening to new ideas, following ethical rules, problem-solving, and proficiency in the field, 20 teacher competencies and 120 performance indicators were confirmed. Among all these competencies, indicators for designing and implementing instruction were emphasized mostly, implying the importance of effective technology integration in teaching. Building on the concept of integrating knowledge within the framework of TPACK, there exist crucial knowledge sets or skills that teachers embodying TPACK or effectively instructing with technology ought to attain. According to Kabakci-Yurdakul et al. (2014), these essential competencies for TPACK-equipped teachers encompass design (i.e., crafting instructional strategies), exertion (i.e., executing instructional plans), ethics (i.e., ethical considerations), and proficiency (i.e., innovative approaches, problem-solving, and subject expertise).

In the related literature, there are further studies shedding light on teachers' TPACK proficiency. To illustrate, in the study by Aktaş and Özmen (2022), video recordings of lesson presentations were used to assess pre-service teachers' practical TPACK skills in a TPACK-practical course. The participants were 46 pre-service science teachers (19 males and 27 females) in Türkiye who took a TPACK-Practical Course consisting of a training course and lesson-plan micro-teaching stages. The study analyzed lesson plans and video recordings to investigate the development of PSTs' practical TPACK skills using an analytical rubric with 12 performance criteria. The criteria include aspects such as drawing students' attention, using technology effectively, ensuring student safety, providing effective feedback, evaluating student learning and adapting teaching to individual differences, among others. These criteria reflect the practical knowledge and skills that teachers need to integrate technology, content, and pedagogy effectively in their teaching practices. The results showed that the PSTs' TPACK proficiency improved significantly after taking the course. The researchers concluded that the TPACK-practical course helped PSTs develop their TPACK skills and provided insights into effective teaching with technology.

In another study conducted by Ogegbo (2023), the aim was to assess the proficiency level of secondary school science teachers in digital competencies using the DigCompEdu framework. The study involved 102 science teachers who completed a questionnaire, and data were analyzed using frequency counts, percentages, means, and standard deviation. The majority of teachers in the sample demonstrated a proficiency level of integrator–B1 in digital skills, indicating a need for improvement in understanding effective tool use and integrating digital technologies into pedagogical approaches. Specifically, teachers exhibited low proficiency in areas such as digital content creation, feedback provision, planning, analyzing students' issues, and organizational communication. These findings underscore the importance of continuous professional development, emphasizing real-classroom applications to enhance science teachers' digital proficiency and better address diverse student needs. The study concludes that science teachers need to be trained and re-trained on the practical use of technology to enhance the teaching and learning process, as well as professional interactions.

Additionally, initiating a comprehensive exploration, Deng et al. (2023) delved into the TPACK of pre-service chemistry teachers, specifically focusing on the utilization of data-logging in the chemistry classroom. Recruiting 181 participants from a reputable university in Guangdong Province, China, the study introduced these pre-service teachers to both data-logging technology and essential TPACK concepts through a dedicated course. Employing a quantitative research approach, the investigation aimed to assess the TPACK proficiency of pre-service chemistry teachers concerning the effective application of data-logging technology in the classroom. The subsequent analysis revealed that all factors related to Data-logging TPACK for pre-service chemistry teachers surpassed average levels, indicating a solid understanding and competency in data-logging TPACK falling between adaptation and exploration. However, despite possessing foundational TPACK knowledge, the study underscored the necessity for further refinement in the TPACK proficiency of pre-service teachers.

In conclusion, these studies collectively contribute to the understanding of TPACK among teachers, shedding light on proficiency levels in their instructional practices in terms of their TPACK for effective teaching in today's digital age. Based on previous studies, the proficiency levels of teachers in terms of TPACK vary across different

dimensions. Some teachers demonstrate higher proficiency, particularly in reflective application, showcasing a deep understanding of integrating technology, pedagogy, and content in their teaching practices. On the other hand, there are instances where teachers exhibit lower proficiency levels, such as in basic adoption or lack of use, indicating challenges or limited use of technology in teaching.

2.2.3. Research on Interplay among TPACK Components

The purpose of this subsection is to provide an overview of studies investigating the interplay or relationship among TPACK components or constructs. This exploration aims to deepen the comprehension of the dynamic and evolving nature of these connections, shedding light on how technological, pedagogical, and content knowledge intersect and influence each other within the TPACK framework.

The development of TPACK in utilizing technology is shaped by the strategic cognition of teachers, necessitating a grasp of when, where, and how to employ domain-specific knowledge and strategies. For instance, Niess (2011) underscored the difficulties and nuances in guiding TPACK development within specific content contexts, proposing that teachers' TPACK development may mirror the advancement of their PCK. Additionally, Niess delved into the complexities of capturing the essence of TPACK, emphasizing the interplay among content, technology, and teaching and learning. She also explored the complications of embedding technology in the classroom, underscoring the intricate interaction of various factors and the necessity for context-specific strategies and representations. Consequently, Niess furnished an all-encompassing comprehension of the interplay among TPACK components, underscoring the dynamic and intricate nature of the relationships among technological, pedagogical, and content knowledge in educational contexts.

A thorough grasp of the interplay among TPACK components denotes a profound understanding of how technological, pedagogical, and content knowledge interconnect and impact one another in educational settings. This comprehension underscores the dynamic and complex nature of the relationships among these knowledge domains. The dynamic aspect implies that the interactions and influences among technological, pedagogical, and content knowledge are not fixed but consistently evolving and adapting to diverse teaching and learning situations. This dynamic interplay mirrors the ever-changing landscape of educational technology and the diverse needs of

students and teachers. Furthermore, Niess (2011) underlines that the complex nature of these relationships suggests that the integration of technology in education involves intricate and multifaceted interactions among the different knowledge components. It recognizes that the effective utilization of technology in teaching and learning necessitates a profound understanding of how these components intersect and shape one another. In summary, a comprehensive understanding of the interplay among TPACK components acknowledges the intricate and evolving relationships among TPACK in educational contexts, emphasizing the requirement for nuanced and context-specific approaches to integrating technology in teaching and learning.

Graham (2011) emphasizes the need for researchers to conduct analyses uncovering insights into how knowledge bases interact. The dynamic and intricate interplay within TPACK knowledge components is a multifaceted process, where the second-level knowledge basis (TPK, TCK, PCK) plays a crucial role in influencing TPACK development. This perspective is corroborated by the study conducted by Pamuk et al. (2015), where the interplay among TPACK components was explored through the examination of preservice teachers' experiences. In this study, a research instrument was meticulously developed and validated to measure teachers' technology integration knowledge and experiences within the TPACK framework. The findings of the study revealed significant correlations among all TPACK components. Structural equation modeling analyses underscored the statistically powerful contributions of TPK and TCK in explaining TPACK variance. Importantly, the results suggested that the second-level knowledge bases (TPK, TCK, PCK) had a more substantial impact than the core knowledge base on predicting TPACK development. TCK emerged as a crucial mediator knowledge base within the structural model, highlighting considerable indirect relationships among certain TPACK components. Furthermore, the study posited that the predictive influence of core and second-level knowledge bases on TPACK development significantly differs. Notably, core knowledge bases do not directly impact TPACK, but they play a big role through indirect ways.

The advancement of TPACK is crucial for effective technology-integrated teaching, involving the dynamic interplay among content, pedagogy, and technology knowledge. In the study of Schmidt et al. (2009), they aimed to create and validate a tool for preservice teachers to self-assess their TPACK and related domains within the

framework. Focusing on how preservice teachers develop and apply TPACK, the research explored their experiences during teacher preparation programs and in PK-6 classrooms during practicum and student teaching. The survey instrument, named the Survey of Preservice Teachers' Knowledge of Teaching and Technology, catered specifically to elementary or early childhood education majors, concentrating on literacy, mathematics, science, and social studies. The pilot study, involving 124 preservice teachers, used the survey to collect self-assessment data on the seven TPACK framework knowledge domains. The results illuminated the intricate relationships among TPACK components in the context of preservice teacher education and their readiness to teach diverse content areas. Notably, the study revealed significant correlations between TPACK and eight subscales at the .001 level, as well as with social studies content knowledge (SSCK) at the .05 level. The strongest correlations were found between TPACK and TPK, TPACK and TCK, and TPACK and PCK, underscoring the interconnectedness of these components within the TPACK framework. Consequently, the study provided valuable insights into the relationships and interdependencies among TPACK components, offering a nuanced understanding of teachers' complex knowledge for effectively integrating technology into their teaching practices.

Aiming to scrutinize the connections among TPACK components, Celik et al. (2014) emphasized the central role of pedagogy in TPACK using a structural equation model. The study involved a sample of 744 preservice teachers from Türkiye. Data were gathered using a survey developed, featuring seven subscales designed to measure TPACK levels. The findings suggested a significant correlation between technology knowledge and pedagogy and content knowledge, indicating that pedagogy serves as the core knowledge of TPACK. Furthermore, the study revealed that only specific dyadic knowledge components, particularly content knowledge, were associated with TPACK, emphasizing the intricate interplay between these elements. Consequently, the study revealed that the relationships between pairs of knowledge, like the dynamic interplay of technology and pedagogy knowledge or the intricate connection between technology and content knowledge, were recognized as significant influencers of TPACK. This emphasized how these specific pairs of knowledge components worked together, showcasing their collective impact on TPACK. In essence, the research underscored the importance of understanding how these specific pairs of knowledge

interacted and relied on each other, playing a crucial role in shaping the comprehensive TPACK framework. This newfound understanding drew attention to the nuanced and interconnected nature of TPACK, providing valuable insights into the specific combinations of knowledge that are essential for fostering TPACK competencies.

In their recent study, Özgen and Narlı (2020) undertook an exploration into the realm of TPACK with the objective of unraveling the intricate interplay among teachers' CK, PK, and TK. The researchers collected data from preservice teachers to assess their TPACK levels. The researchers delved extensively into the domain of TPACK, employing Rough Set Analysis as a methodological approach to navigate the intricate landscape of these interconnected components. The findings exceeded initial expectations, revealing that the relationships among CK, PK, and TK were not only defined poorly but also more intricate and dynamic than initially perceived. This result underscores the necessity for a more profound comprehension of how these elements interact within the TPACK framework. The researchers revealed hidden connections and dependencies among these elements, exposing a complex network of relationships that demonstrates the constantly changing nature of TPACK development.

In a distinct investigation, Khine et al. (2017) investigated preservice teachers' TPACK and ICT achievement. They gathered data from 67 Emirati preservice teachers in the United Arab Emirates. They translated and adapted the English version of the instrument into Arabic. After they ensured linguistic accuracy and cultural relevance through back translation, they affirmed the reliability and validity of the Arabic version of the TPACK survey in the UAE context. Furthermore, the study identified TK, PK, CK, and TPK as significant predictors of TPK, TPACK, and PCK. However, CK showed no significant relation to PCK, and PCK did not significantly relate to TPACK. The findings also revealed moderate positive correlations between ICT achievement and TK, CK, TPK, and TPACK.

Akyuz (2018) sought to elucidate the connections among elements within the TPACK framework and to outline the process of assessing TPACK. The study involved 138 preservice mathematics teachers participating in a five-year technology integration course. Data were collected using a TPACK assessment tool, comprising seven knowledge domains with three items each. The findings indicated the interconnected

nature of TPACK components, emphasizing the interrelatedness of these knowledge domains. Notably, the study highlighted the significance of using technology to facilitate students in making conjectures or generalizations, identifying it as a crucial component within the TPACK framework. This underscores the pivotal role of technology in fostering higher-order thinking skills and conceptual understanding among preservice mathematics teachers. Emphasizing this role is crucial for effective TPACK assessment and development.

In a more recent study, Chen and Hsu (2021) delved into the reflections of the COVID-19 pandemic on teachers' TPACK (Technology, learners, pedagogy, academic discipline content, and content knowledge), with a specific focus on the interplay between its components. The study included 250 teachers in each group, and data were gathered through a questionnaire aligned with Hsu and Chen's TPACK model. The findings unveiled notable differences in teachers' TPACK before and during the pandemic, indicating alterations in technological, pedagogical, content, learner, and context knowledge. Beyond these disparities, the study sought to furnish a holistic comprehension of how diverse TPACK components intersect and exert influence within the teaching context, both pre and post the COVID-19 pandemic. This involved investigating the interconnectedness of teachers' technological, pedagogical, content, learner, and context knowledge, exploring how modifications in one component could reverberate across others. Through an exploration of these relationships, the study aimed to offer a more nuanced insight into teachers' preparedness and adaptability amid the sudden transition to online education during the pandemic.

Similarly, Mourlam et al. (2021) investigated the impact of the COVID-19 pandemic on teachers' TPACK knowledge and instructional methods. The study involved 167 in-service teachers from the Midwestern United States. They used a self-report TPACK tool with 36 items covering different TPACK areas. The research acknowledged the influence of changes in how teachers reported their TPACK before and during the pandemic on the collaborative functioning of these TPACK elements. Notable distinctions in teachers' TPACK before and during the pandemic emerged through the application of related-samples t-tests to the data. The research revealed that there was decline in five of the seven TPACK domains of teachers due to impact of the COVID-19 pandemic. The authors suggested that the interplay among TPACK

elements was influenced by the instructional context, shaping how teachers reported their knowledge. Specifically, the study underscored the interconnected nature of TK and TCK. This indicated that during the shift to remote instruction, teachers likely needed to enhance their knowledge of various technology tools, potentially explaining why TK did not decrease significantly. Additionally, the research stressed the importance of understanding the interplay between PCK and other TPACK domains. This suggested that changes in PCK might have influenced teachers' confidence and, consequently, their self-reported TPACK.

Likewise, the relationship between the basic domains of the TPACK framework and TPACK of pre-service elementary special education teachers was analyzed by Kaplon-Schilis and Lyublinskaya (2020). Instruments were developed and validated to measure TK in mathematics and science, PK, and CK, focusing on the interplay between these constructs and TPACK. The sample, consisting of 116 pre-service elementary special education teachers, was utilized for data collection through instruments designed to assess participants' basic knowledge and TPACK development. Significant relationships between TPACK domains were identified, emphasizing the interplay among TK, PK, CK Math, CK Science, and TPACK. The interconnected nature of these domains within the TPACK framework was underscored by the study. This indicates that these domains are not isolated but rather interact and influence each other in teachers' knowledge and practice. For instance, a strong foundation in TK was found to positively influence TPACK development, highlighting the interconnectedness of these knowledge domains.

A valid and reliable short questionnaire for measuring TPACK (TPACK.xs) was developed by Schmid et al. (2020), aiming to investigate its internal structure and relationships between individual components. A total of 117 pre-service upper secondary school teachers, participated in the study, and data were collected using an initial 42-item questionnaire. Results indicated that the final TPACK.xs questionnaire, comprising 28 items, is a valid and reliable instrument for assessing pre-service teachers' TPACK. The study also discovered that the internal relationships among various TPACK components support a transformative view of the TPACK model. Specifically, TPACK, the intersection of PCK, CK, and TCK, was found to be primarily influenced by the hybrid components TPK and PCK. This suggests that

integrating technology into teaching involves a transformative process, creating new knowledge at the intersection of these domains, rather than merely adding technological knowledge to pedagogical and content knowledge.

In the dynamics of TPACK, teachers' perspectives play a crucial role in shaping the connections among its components. Koh et al. (2013) delved into this complexity, aiming to uncover how TPACK elements interact and influence teachers' proficiency in ICT. With a cohort of 455 teachers in Singapore, the TPACK survey for Meaningful Learning took center stage. The results revealed that teachers shape their TPACK framework through the direct influences of TK and PK, forming the constructs of TPK and TCK. Nevertheless, the roles of CK and PCK were subtly woven into teachers' TPACK conceptions. Notably, the attention was on TPK and TCK, guiding the TPACK dynamics more prominently compared to TK and PK. This suggests that refining TK skills should be a pivotal aspect of teachers' journey, enabling them to navigate the rhythm of ICT tools and their potentials effectively.

The development of TPACK is also molded by contextual factors encompassing elements like the accessibility of technology and institutional regulations. In an endeavor by Koh et al. (2014), an exploration was undertaken to scrutinize how the construction of TPACK by teachers is swayed by contextual factors. The sample of the study involved 24 school teachers from three levels of an elementary school in Singapore. Data gathering was conducted through discussions on lesson planning and interviews. The findings illuminated that the co-construction of TPACK was subject to the influence of contextual factors, spanning cultural/institutional, intrapersonal, and interpersonal interactions. The intricate interactions between TPACK components were observed to be intricately influenced by these contextual factors. This highlights that the shaping of TPACK is molded by contextual factors such as cultural and institutional interactions, intrapersonal dynamics, and interpersonal exchanges. Cultural and institutional factors, covering school policies and practical considerations, were at times identified to dominate discussions, potentially constraining the emergence of TPACK. Conversely, when considering intrapersonal factors such as teachers' beliefs about teaching and students, it facilitated the development of TPACK. Additionally, the study disclosed that the presence of robust facilitators, exemplified by experienced educational technologists, led to heightened

instances of TPACK in the discussions. These revelations underscore the intricate and dynamic nature of TPACK development, intricately influenced by the interplay of contextual influences and the interactions between its components.

The study by Yeh et al. (2015c) emphasized the dynamic and intricate nature of TPACK-P, portraying it not as a fixed knowledge set but as a cohesive construct that evolves with time and experience. To grasp this concept, the researchers sought to develop and validate a rubric for assessing science teachers' TPACK-P, using their analytical comments in response to video-based instructional prompts. The participant pool comprised 120 science teachers from Taiwan, varying in teaching experience and educational backgrounds. Employing an online questionnaire, the researchers gauged teachers' TPACK-P by prompting them to analyze and critique video-based instructional prompts. Three primary TPACK-P components namely, assessment, planning and designing, and practical teaching were identified to emphasize the interconnectedness of these elements. The researchers highlighted the interplay between these components, emphasizing how they are interconnected and influence each other in the context of TPACK-P. For instance, effective assessment practices inform the planning and designing of technology-integrated lessons, while practical teaching experiences provide valuable feedback for refining assessment and instructional strategies. This interconnectedness underscores the holistic nature of TPACK-P and the need for teachers to develop proficiency across all three components to effectively integrate technology into their teaching practices. The findings suggested that teachers may demonstrate varying proficiency levels in different aspects of TPACK-P, highlighting the necessity for a comprehensive evaluation of TPACK-P components. This emphasizes the holistic nature of TPACK-P, requiring a nuanced and multifaceted approach to evaluation. Recognizing the interplay among different TPACK-P components enables educators to better support teachers in developing TPACK-P and enhancing instructional practices.

In light of the studies mentioned above, it is evident the existence of intricate relationships and interdependence among many TPACK components such as technological, pedagogical, and content knowledge. The dynamic and ever-evolving nature of these connections prevails consistently across varying contexts and methodologies. It is understood that many components, especially TPK, TCK, and

PCK, play a pivotal role in shaping the development and incorporation of TPACK. Although studies in the literature have predominantly investigated these relationships according to Mishra and Kohler's (2006) TPACK framework, research exploring the relationships among the components of the TPACK-P framework has been quite limited. Nevertheless, it is clear that these knowledge bases are deeply interconnected, underscoring the need for a nuanced understanding of how they collaborate and influence one another. Furthermore, the impact of cultural influences and the complexities of incorporating technology must not be overlooked, as they play a significant role in shaping this interplay.

2.2.4. Research on TPACK Studies related to Force and Energy Topics

When reviewing the existing literature, it becomes evident that there is a notable scarcity of research specifically examining the topic-specific TPACK of science teachers when addressing subjects such as force, motion, and energy. However, a limited number of studies, encompassing both in-service science teachers and pre-service science teachers, have been briefly outlined in this subsection.

In the domain of studies examining TPACK when teaching force, energy, and related topics, valuable insights are contributed by Timur's (2011) research. For example, Timur (2011) study's focus was the investigation of TPACK development among pre-service science teachers, specifically within the context of force and motion units. Employing a mixed methods research design, 30 senior pre-service science teachers were engaged in a technology and project design course. The findings indicated that technology-supported teaching had a positive influence on the TPACK confidences, self-efficacy beliefs toward computer use in science teaching, and cognitive structures of pre-service teachers. Notably, it was observed that technology-supported teaching effectively enhanced four components of TPACK, encompassing knowledge of purpose, curriculum and curriculum materials, instructional strategies and assessment, and teaching with technology. While the gradual nature of TPACK development and challenges in specific dimensions were acknowledged, Timur's research made significant contributions to understanding how technology-supported teaching impacts TPACK, particularly in the domain of force, motion, and related topics.

Shifting focus to Şentürk's (2017) meticulous investigation, the primary objective was

to explore teachers' TPACK levels in the context of incorporating animation and simulations into physics teaching. This involved integrating animation and simulations, specifically designed for the 9th-grade Force and Motion topics through professional development. The study selected four physics teachers who underwent professional development, observing their classes and gathering their perspectives. Data, including observation notes, interviews, videos, and voice recordings, were analyzed using descriptive methods. Content knowledge on Force and Motion was assessed through tests, and results were compared with Animation and Simulations-TPACK competencies. Findings indicated that participants with teaching experience using technology and fewer years of service (15-18 years) demonstrated sufficient Animation and Simulations-TPACK. In contrast, those without teaching tech experience and more seniority (22-31 years) showed inadequate Animation and Simulations-TPACK. The study emphasized the need for technology-focused professional development for all participants, with the provided sessions effectively addressing these needs. Thus, Şentürk's (2017) study highlights the crucial interplay between teaching experience, professional development, and TPACK proficiency. Teachers with prior technology integration experience and fewer years of service exhibited sufficient Animation and Simulations-TPACK, underscoring the impact of hands-on teaching involvement. Conversely, those lacking tech-teaching exposure and having higher seniority displayed inadequate TPACK, emphasizing the need for continuous professional development throughout teachers' careers.

Moving on to Tasar and Timur's (2010) in-depth exploration, they investigated the progression of TPACK among second-year pre-service science teachers enrolled in a computer course with a focus on microteaching. During the microteaching, eight pre-service science teachers taught Force and Motion units from the 6th, 7th, and 8th-grade primary curriculum using inquiry-based interactive physics computer animations. Using a mixed methods research design, the study employed both qualitative and quantitative methodologies to assess TPACK development. A one-group pretest-posttest design was utilized to measure the evolution of TPACK. The TPACK in Science Survey was administered to 38 pre-service science teachers. The results revealed a significant enhancement in confidence across all four TPACK constructs, which were TK, TPK, TCK, and overall TPACK.

In Avcı's (2017) research, the aim was to investigate the impact of teacher candidates engaging in Lego Mindstorm Robotics Projects on their TPACK, problem-solving abilities, and scientific creativity. The study involved 20 preservice science teachers from Türkiye. Using a mixed-method research model, the research spanned 10 weeks and focused on the effects of Lego Mindstorm robotics projects on technological pedagogical content knowledge, problem-solving skills, and scientific creativity. During the project activities, the participants created different projects on physics and biology topics such as force and motion, simple machines, and genetic engineering. The research employed various instruments, including adapted tests for scientific creativity, technological pedagogical content, and problem-solving skills. Qualitative data, obtained through content analysis, descriptive analysis, and document analysis, were complemented by quantitative data analyzed using the Wilcoxon signed-rank test in SPSS. The findings indicated favorable results in post-tests for technological pedagogical field knowledge and the scientific creativity test. However, there were no significant improvements in certain subcategories of the test of technological pedagogical content knowledge. Interestingly, the results for problem-solving skills favored the pre-tests. Overall, teacher candidates expressed positive opinions on the use of Lego Mindstorm robotic projects in science lessons based on qualitative data collected in the study.

Although these studies collectively emphasize the growing importance of exploring and understanding teachers' TPACK in the domains of force, motion, and energy. However, the scarcity of research on the topic-specific TPACK of science teachers in the domains of force, motion, and energy highlights a critical gap in the existing literature. Understanding the dynamics of TPACK in these specific areas is crucial for effective science education.

2.3. Summary of the Literature Review

The conceptual framework of TPACK is foundational in understanding the intricate relationships among PK, CK, and TK. Originating from Shulman's PCK, TPACK was introduced by Mishra and Koehler in response to the growing demand for effective technology integration in education. PK involves methods, techniques, and processes of teaching and learning, while CK focuses on subject matter content. TK,

encompassing both old and new technologies, intersects with CK to form TCK, emphasizing the transformation of content using specific technologies. Likewise, TPK covers the knowledge of which technologies are developed to use in teaching, and the knowledge of using these technologies with necessary pedagogical knowledge. TPACK, positioned at the heart of the TPACK framework, represents the dynamic relationship among PK, CK, and TK, emphasizing the need for teachers to navigate this interplay for effective teaching with technology.

Two views on TPACK, namely integrative and transformative, shed light on its development. The integrative view posits that enhancing components of TPACK, namely PK, CK, and TK, contributes to overall TPACK improvement. In contrast, the transformative view argues that TPACK development is a complex process, requiring explicit training toward the whole construct rather than individual knowledge types. The epistemological nature of TPACK is discussed through graphical representations, such as the TPACK framework by Mishra and Koehler, and the transformative TPACK-ICT model by Angeli and Valanides (2009). The question of whether TPACK is domain-generic or domain-specific is argued, considering contextual factors and the unique characteristics of TPACK in different teaching domains.

The TPACK-P framework, proposed by Yeh et al. (2014), emphasizes the interconnected nature of TPACK within specific content areas. Visualized as a circular framework, it comprises five pedagogical areas and eight knowledge dimensions, highlighting the role of ICTs in teaching. The framework's iterative nature and the importance of teaching experience in TPACK development are stressed. It includes eight knowledge dimensions, covering areas like assessment, learners, subject content, curriculum design, and practical teaching. Competencies in using ICT for student evaluation, understanding diverse student characteristics, integrating technology into specific subjects, and planning ICT-infused curriculum are emphasized. The framework recognizes the central role of teacher application knowledge and PCK in regulating the teaching process. Core elements such as learners, pedagogy, representations, and tool affordances are crucial for shaping teachers' TPACK. A comparison between TPACK and TPACK-P components reveals alignments in TPK, TCK, and TPACK, showcasing the interconnectedness of technology, pedagogy, and content knowledge in TPACK-P.

The extensive body of research on TPACK explores various dimensions, primarily focusing on proficiency levels among teachers. TPACK assessment has been a key area of interest since its inception, with self-assessment surveys as predominant tools. Concerns about survey reliability have led to the exploration of alternative tools such as performance-based assessments, interviews, and observation reports. Qualitative methods, including interviews and performance assessments, provide valuable insights into teachers' thought processes. TPACK proficiency studies, particularly using the TPACK-P framework, categorize teachers' competency levels based on their performances in actual teaching practices. Beyond TPACK-P, other frameworks and methodologies contribute to understanding TPACK proficiency levels, emphasizing the intricate interplay of technology, pedagogy, and content knowledge in teachers' instructional practices.

Research on TPACK proficiency delves into the competency levels of both in-service and pre-service science teachers. The TPACK-P framework is instrumental in assessing teachers' proficiency, emphasizing the importance of evaluating their performances in actual teaching rather than merely measuring knowledge components. Studies categorize TPACK proficiency into levels, such as no idea, lack of use, simple adoption, infusive application, and reflective application, based on teachers' actions and strategies. Validation of TPACK-P frameworks and determination of proficiency levels reveal that while there might be no significant differences between in-service and pre-service teachers, practical applications often lag behind comprehension levels. Various studies explore teachers' behaviors, views, and competencies across different TPACK proficiency levels, offering insights into their ability to integrate technology effectively into teaching practices. Beyond TPACK-P, other frameworks, such as TPACK-Deep, contribute to a comprehensive understanding of TPACK proficiency, shedding light on factors like design, exertion, ethics, and proficiency. These studies collectively underscore the significance of science teacher education programs in developing TPACK proficiency and the need for continuous professional development to enhance digital competencies among teachers.

Research on the interplay among TPACK components reveals a dynamic and evolving relationship between technological, pedagogical, and content knowledge. The studies, such as those by Niess (2011), Pamuk et al. (2015), and Schmidt et al. (2009),

emphasize the intricate connections, highlighting challenges in guiding TPACK development within specific content contexts and the significant impact of second-level knowledge bases (TPK, TCK, PCK). Recent investigations by Özgen and Narlı (2020), Chen and Hsu (2021), and Mourlam et al. (2021) explore TPACK dynamics during the COVID-19 pandemic, indicating changes in teachers' TPACK. The findings underscore the dynamic nature of these relationships and the need for a comprehensive understanding to facilitate effective technology integration in education.



CHAPTER 3

METHODOLOGY

In this chapter, the philosophy underlying this research, research design, selection of participants, data collection tools, and data analysis, pilot study, trustworthiness of the study were addressed in detail. Since the aim of this study was two-fold, two research questions were determined as follow:

- What are the proficiency levels of in-service science teachers' TPACK-P in teaching force and energy topics?
- What is the nature of interplay among the five TPACK-P components of in-service science teachers in teaching force and energy topics?

3.1. The Philosophical Orientation

Qualitative research is underpinned by diverse philosophical perspectives, with each researcher interpreting and applying these foundations uniquely. Central to qualitative research is the philosophical understanding of reality (ontology) and knowledge (epistemology). This study follows a constructivist approach, consistent with the interpretive case study methodology advocated by Merriam and Tisdell (2016). In this approach, there is no single, observable reality; instead, reality is considered to be socially produced, allowing for multiple interpretations of a single event. Constructivist research aligns with a constructivist ontological perspective, emphasizing that meaning and knowledge are generated socially and experientially, contributing to the intersubjective construction of reality.

For this study, this alignment with Merriam and Tisdell's constructivist viewpoint serves the purpose of comprehending the nature of science teachers' TPACK in their school context. It emphasizes the importance of context-specific understanding and goes beyond the positivist quest for universal laws. Furthermore, the commitment to

Merriam and Tisdell's pragmatic epistemological orientation is evident in the diligent use of impartial procedures for collecting, organizing, and evaluating extensive and abstract data. This influence permeates various aspects of the study. For example, the research design provides a rich and comprehensive depiction of the teachers and their teaching experiences. Additionally, the transparency in detailing the data collection and analysis processes, along with presenting evidence from interviews and observations, enhances the clarity of the interpretations.

In summary, the philosophical orientation of constructivism and pragmatic epistemology informs the study's approach and significantly enhances the depth and reliability of the research outcomes by fostering context-specific understanding as well as transparent and impartial data handling.

3.2. Research Design

This study adopts a qualitative research methodology to explore the complex aspects of science teachers' TPACK-P. Qualitative research is well-suited for this purpose as it focuses on understanding the meaning individuals attribute to their experiences and how they construct their understanding of the world (Merriam & Tisdell, 2016; Patton, 2015). Rather than seeking cause-and-effect relationships or statistical distributions within a population, qualitative research delves into the intricate nature of TPACK-P among science teachers. The selection of a qualitative design was primarily driven by the need to collect rich and detailed information about the TPACK-P of in-service science teachers. This approach enabled the gathering of substantial evidence and insights into the proficiency levels of science teachers' TPACK-P and uncovered how TPACK-P components interacted with each other. Furthermore, the qualitative methodology was essential in addressing the specific research objectives of this study. TPACK-P is highly dependent on the personal context and teaching practices of individuals, making it unsuitable for quantitative research that relies on self-reported surveys and statistical analyses. To gain a comprehensive understanding of TPACK-P, it is crucial to collect data directly from teachers, capturing their actions, opinions, and the contextual details that shape their TPACK-P.

Qualitative case study method was selected for this study because case studies focus on conducting a detailed examination of a particular of subject, document, setting, or

event. Case studies provide an empirical approach for exploring cases in-depth within their real-world settings. This method allows for in-depth investigation, especially when the boundaries between phenomena and context are unclear (Yin, 2015). Given the focus of the research as exploring proficiency levels and the interactions of TPACK-P components in science teachers' teaching context, a qualitative case study was deemed well-suited for this purpose.

Case studies can focus on one single case or more cases defined in a bounded system (Merriam & Tisdell, 2016; Yin, 2015). A bounded system describes the boundaries of a case by time, place, or other specific conditions for research purposes. Since this study focused on a comprehensive examination of four in-service science teacher's TPACK-P proficiency and the nature of the interplay among TPACK-P components, this study was designed as *multiple case study*. This approach allowed for an in-depth exploration of the intricacies of TPACK-P in the context of teaching force and energy topics. Consequently, *the cases* involve four in-service science teachers who teach force and energy topics using technology-based instructional practices. Furthermore, the study was delimited by specific places and a time frame. These *specific boundaries* were defined as four classrooms within one urban public middle school located in a small province of the South Eastern Anatolian Region of Türkiye during the 2021-2022 Fall semester.

In the context of this study, two distinct research questions were formulated. Thus, these questions demanded different units of analysis to provide in-depth insights. Accordingly, the unit of analysis was the *in-service science teachers* for the first research question. Proficiency levels, which were a qualitative assessment, were determined at the individual teacher level based on their instructional practices. In contrast, the second research question focused on the intricate interactions among TPACK-P components. To delve into these relationships, the unit of analysis shifted to TPACK episodes, which were instances within teachers' instructional practices where TPACK-P components were prominently intersected. These episodes were derived from data gathered through observations and interviews.

Table 2 presents a concise summary of the research design matrix, illustrating the methodological approach adopted to investigate the study's dual research questions

Table 2. Research design matrix of the study

	Research Question 1	Research Question 2
What do I need to know? (Research Questions)	What are the proficiency levels of in-service science teachers' TPACK-P in teaching force and energy topics?	What is the nature of interplay among the five TPACK-P components of in-service science teachers in teaching force and energy topics?
Why do I need to know this?	To discover and assess in-service science teachers' TPACK-P proficiency level	To discover the interactions among TPACK-P components of in-service science teachers'
What kind of data answered the questions?	Observations of science teaching performances Semi-structured interview questions By observing class performances while they were teaching the topics of force and energy to 7th-grade students	Observations of science teaching performances Semi-structured interview questions By observing class performances while they were teaching the topics of force and energy to 7th-grade students
How did I find the data?	Interviewing four science teachers	Interviewing four science teachers
Whom did I contact for data access?	Science teachers who teach force and motion unit to 7th-grade students in one public middle school	
	Organizing the data by transcribing the observations and interviews Labelling data points based on each subcategory according to the rubric	Organizing the data by transcribing the observations and interviews Coding the data to explore TPACK episodes
How did I analyze the data?	Scoring each data point Categorizing the proficiency levels Verifying the measures to validate Finalizing the categorization of the proficiency levels	Generating categories to analyze interplays Enumerative approach to present all interplays of each case by mapping Constant-comparative method to diagnose common patterns and formulate assertions
When did I collect data?	Interview data: After completion of teaching force and energy unit Observation data: During teaching force and energy unit	
How did I handle trustworthiness issues?	Credibility: triangulation of data sources; member check; adequate time spent; reflexivity; peer examination Consistency: triangulation of data sources; peer examination; reflexivity; audit trail Transferability: rich and thick descriptions; purposive sampling	
How long did I spare time for data collection?	Interviews: Ranging from 63 to 102 minutes each Observations: Ranging from 10 to 15 class hours each	
When was timeline of acquisitions	From November 2021 to January 2022 for the main study	

centered on exploring the TPACK-P proficiency of in-service science teachers and the intricate interactions among its components. The matrix outlines key elements, including research questions, rationale, data types and sources, data acquisition and analysis methodology, trustworthiness measures, timeline of data collection, and participant engagement duration.

3.3. Selection of the Participants

In contrast to the various qualitative research types, qualitative case studies typically require two levels of sampling (Merriam & Tisdell, 2016). Surely, qualitative research needs purposeful selection of suitable subjects aligned with the researcher's study objectives. Therefore, this case study aimed to identify the most appropriate cases that align with its research goals. When selecting cases, it was crucial to assess their suitability concerning the research problem, available time, and resources, as recommended by Yin (2015). To ensure this, consultations with relevant individuals and institutions were sought.

Once the cases were identified as science teachers implementing ICT-infused teaching methods for force and motion topics, the next step was to determine the most representative cases from various options. Following Merriam and Tisdell's two-level sampling approach, the researcher focused on geographical factors that allowed for easier access to schools and teachers during the intensive data collection phase within the limited time frame. For this study, a province located in the southeast region of Türkiye was selected as the primary research site. This decision was made to facilitate the investigation process, the researcher targeted locations within their affordable reach, considering both time and logistical factors. Consequently, the first level of sampling was conducted as convenience sampling.

Subsequently, the researcher sought information about the public schools in the selected province from an authorized supervisor in Provincial Directorate for the National Ministry of Education. Based on his consultation, it was understood that four schools were technically eligible to for data collection in terms of the schools' technology infrastructure conditions. Afterwards, the researcher visited all of these schools to meet the school administration and science teachers working there. After becoming acquainted with the teachers, the researcher engaged in informal

conversations and posed several questions to assess whether they were suitable candidates for the study. These informal interviews resembled everyday conversations. Based on the teachers' responses, the researcher made notes and subsequently determined their eligibility to participate in the study. These preliminary interviews provided insights into both the teachers' willingness and their adequacy to take part in the study.

☐ Yes/Often ☐ No/Rarely	Preliminary question: Do you use <u>various ICT tools</u> such as smartboards, internet, other hardware, and educational software before and/or during your science classes?
If the candidate teacher's responses are or closely resemble "Yes/Often", then the researcher proceeds to ask the next set of questions below. Otherwise, the candidate teacher is not qualified for the study.	
☐ Never or rarely ☐ Occasionally ☐ Frequently or always	Question 1. How often do you plan/design your science classes to use <u>various ICT tools</u> such as smartboards, internet, other hardware, and educational software?
☐ Never or rarely ☐ Occasionally ☐ Frequently or always	Question 2. How often do you use <u>various ICT tools</u> such as smartboards, internet, other hardware, and educational software related to your science class during the class ?
☐ Never or rarely ☐ Occasionally ☐ Frequently or always	Question 3. How often do you use <u>various ICT tools</u> such as smartboards, internet, other hardware, and educational software to assess your students in your science classes?
If all three responses from the candidate teacher are "Frequently or Always", then the candidate teacher is deemed eligible for the study. Otherwise, the candidate teacher is not qualified for the study.	

Figure 4. Selection criteria protocol for participants

In particular, to facilitate the participant selection process, the researcher created a short protocol consisting four questions, outlining the criteria for selecting the teachers best suited for the study as illustrated in Figure 4. The first question in this protocol aimed to determine whether the candidate teacher used ICT tools in their classes in general. If the researcher assessed the response of the candidate teacher as 'no' or 'rarely', then the researcher politely thanked to the teacher, understanding that candidate teacher could not participate in the study. On the other hand, if the response was 'yes' or 'often', the researcher proceeded to next questions. The following

questions were asked to ensure whether they used ICT tools during all aspects of their teaching, such as planning and assessing purposes, as well as in-class use. Based on the responses, the researcher determined the candidate teachers as participants only if all their answers to questions were frequently or always, implying that they might provide valuable information about their TPACK-P proficiency and the nature of their TPACK-P.

Another criterion for sample selection was the content of what the teachers teach in their classes. The participants must teach the seventh-grade science topic Force and Energy to students. Because some teachers did not teach to 7th grade students, they were decided not to be participant of this study. Consequently, four teachers who were in the same school and taught at least one 7th grade were determined as participants because they stated that they frequently used ICT tools in their teaching.

Overall, since all the participants were selected aforementioned criteria, the second level of this type of purposive sampling technique is criterion sampling. The criteria were employed to identify teachers who met the predetermined criterion of importance, which was their frequent or regular utilization of ICT tools in teaching 7th grade force and motion unit. This approach aligns with the rationale behind criterion sampling, wherein cases (teachers) that meet specific criteria (frequent or always using ICT tools in three aspect of their teaching, and teaching 7th grade) were chosen for thorough examination to gain insights the topic under investigation within this study. Ultimately, this two-tier purposive sampling technique employed in this study can be specifically labeled as *criterion-based convenience sampling*.

Based on this sampling technique, four in-service science teachers were determined as the participants of the study. Table 3 provides detailed information about each of them. Accordingly, these teachers had different teaching experiences. Among these teachers, one was female, and three were male, with ages ranging from 29 to 46. In Table 3 below, their pseudonyms, some demographic information, fields of graduation, and their teaching experience can be found. From this table, it can be understood that each teacher has a different professional background and experience. For instance, Participant Bora and participant Asaf stand out with their extensive professional experience, while participant Esin is notable for having both undergraduate and

graduate degrees in science education. On the other hand, only participant Cenk appears to have a teaching experience in both private and public schools.

Table 3. The overview of participants' characteristics

Teacher pseudonym	Gender	Age	Education level and field	Teaching experience	ICT training overview
ASAF	Male	46	Chemistry education, B.S.	24 years in public schools	Basic Computer Science Course Trained in Computer Use, EBA Content Development, and Vitamin Adaptive Learning System
BORA	Male	45	Chemistry education, B.S.	24 years in public schools	A course related to ICT Trained in Office programs, IT Mentor Teacher Training, EBA Content Development
CENK	Male	31	Science education, B.S.	7 years in public and private schools	Communication and Basic Computer Literacy Course
ESIN	Female	29	Science education, B.S. Science Education, M.S.	5 years in public schools	Computer Science and Instructional Techn. and Material Design, Conscious and Safe Use of IT and the Internet Courses Trained in Office programs and multimedia design

In addition, the decision to employ a multiple-case study design was driven by the research goal of obtaining a comprehensive understanding of science teachers' TPACK-P proficiency and the nature of interplay among TPACK-P components in teaching force and motion topics. The fact that the selected science teachers had different backgrounds and experiences contributed to the study's ability to achieve the research objectives. For example, the inclusion of more experienced teachers, Asaf and Bora, brings unique perspectives to the study. Being a 'formator,' Bora stands out due to his advanced technological knowledge. In contrast, Cenk and Esin represent a relatively less experienced cohort. Cenk's prior experience in a private school adds an interesting dimension, considering the typically superior technology infrastructure in such institutions compared to public schools. This distinction makes Cenk's case

particularly noteworthy. Esin's master's degree in science education indeed contributes an additional layer of diversity to the study. Through the exploration of various contexts, the multiple-case study design facilitates a more in-depth examination of science teachers' TPACK-P proficiency and the intricate interplay among their TPACK-P components. This design choice aligns with the qualitative nature of the research, aiming to uncover nuanced insights and patterns within the complex context of science education.

3.3.1. Participant Asaf

Participant Asaf is a male teacher who was 46 years old and served 24 years of teaching experience. He carried a weekly teaching load of 20 regular hours and an additional 4 hours dedicated to extracurricular activities. Asaf's educational background includes a degree in Chemistry Education. Regarding his training in ICT, Asaf had taken undergraduate courses in Basic Computer Science. He furthered his ICT skills through specialized professional development training including Computer Usage, EBA Content Development Course, and Vitamin Course.

Asaf described himself as a teacher committed to ensuring that his students have the opportunity to engage in all class activities all the time. In other words, he acknowledged that he occasionally lagged behind the curriculum schedule but emphasized his desire for his students to actively participate in all activities. This approach highlights his dedication to providing students with a rich and inclusive learning experience.

Asaf's extensive teaching experience and expertise in ICT, as demonstrated by his participation in various ICT-related courses, made him a valuable asset to the study. His commitment to student engagement and comprehensive learning aligned with the study's objectives and contributed to the research findings.

3.3.2. Participant Bora

Participant Bora, a male teacher, was 45 years old. With 24 years of teaching experience, he had a weekly teaching load of 24 hours. He graduated in 1998 with a degree in Chemistry Education. Although he stated that he could not remember the course he took related to ICT, Bora stated that he had received professional

development training in ICT, including Office programs, Information Technologies (IT) Mentor Teacher Training, EBA Content Preparation Seminars. Additionally, Bora mentioned that he worked as a mentor teacher, known as a *formatör* in the Turkish context. In this role, he said that he addresses issues related to smart boards and other technology applications in many schools, helping troubleshoot problems and assisting with installations.

Bora's teaching style in terms of ICT use seems to be pragmatic. Bora mentioned his strong inclination towards technology and had a high level of interest in exploring computer programs and the internet. Nonetheless, he also expressed his belief that they were not software developers as science teachers but should focus on acquiring knowledge effectively. Therefore, Bora described himself as a teacher who preferred using ready-made educational content over developing his own, believing that professionally developed materials were more successful.

As an IT mentor teacher, Bora's active involvement in addressing technological issues in various schools further amplified the significance of his contribution to this research. His pragmatic approach to ICT use, combined with a strong interest in technology, added valuable dimensions to the exploration of science teachers' TPACK-P within the complex landscape of force and motion topics.

3.3.3. Participant Cenk

Participant Cenk, a male teacher, was 31 years old at the time of the study and had accumulated seven years of teaching experience. He had a weekly teaching load of 20 hours and graduated with a degree in Science Education. In terms of his training in ICT, Cenk stated that he had taken undergraduate courses in communication and basic computer literacy, providing him with a foundational understanding of ICT.

Cenk's teaching approach revolves around creating a structured environment that actively involves students in the learning process. He expressed his goal of offering opportunities for each student to engage actively in technology-supported learning experiences. However, he noted that transitioning from teaching in private schools, where the focus was primarily on academic achievement, to a public-school environment initially posed challenges for him. During this adaptation process, Cenk

highlighted the pivotal role played by Asaf, who was his mentor teacher at that time, in facilitating his integration into the public school system.

Cenk stood out for his dedication to covering the curriculum within the recommended timeframes. Compared to his colleagues, he tended to complete the theoretical content earlier, allowing more time for revision and extensive practice through problem-solving activities. This approach reflected his commitment to ensuring that his students had a solid understanding of the subjects he taught. Moreover, along with his experiences in private school where technology infrastructure was better than the current school, Cenk provided distinctive insights to the study.

3.3.4. Participant Esin

Participant Esin is a female teacher who was 29 years old at the time of the study and possessed five years of teaching experience. Her weekly teaching load consisted of 18 hours of regular classes and an additional 2 hours for extracurricular activities. Esin held Bachelor's and Master's degrees in Science Education. In terms of her training in ICT, Esin had taken undergraduate courses such as Computer Science and Instructional Technologies and Material Design. She further enhanced her ICT skills during her postgraduate studies, where she learned about Word, PowerPoint, spreadsheet preparation, and multimedia design (e.g., Powtoon). Esin also completed a course on 'Conscious and Safe Use of Information Technologies and the Internet', emphasizing her commitment to promoting safe and responsible ICT use among students.

Esin's teaching approach was characterized by her diverse ICT skill set, including multimedia design, which allowed her to create engaging and interactive learning materials. Her dedication to ensuring a safe digital learning environment aligned with her participation in courses related to responsible ICT use. Esin's combination of theoretical knowledge and practical skills, along with her academic background, made her a valuable contributor to the study.

3.4. Selection of the Subject Matter

The deliberate choice to center this study on the force and energy learning unit is

underpinned by several strategic considerations. Foremost among these is the inherent complexity and abstract nature of these physics concepts, which have been widely acknowledged as challenging for students (Tuncel & Fidan, 2018). As these physics concepts are recognized for their abstract and challenging nature, presenting difficulties for students through traditional teaching methods, especially in a digital era where students are highly engaged with technology, the study aligns with modern pedagogical trends (Kakhkhorov & Rasulova, 2020). By focusing on force and energy units, the research aims to explore science teachers' TPACK in the specific context of teaching these challenging topics, offering insights into how educators leverage technology and modern pedagogical approaches to enhance student comprehension.

By specifically selecting force and energy units, the study sets out to unravel the intricacies of science teachers' TPACK by closely examining how they harness technology, including ICT tools and associated pedagogies, to teach these challenging topics. This intentional focus seeks to explore the innovative ways in which technology is integrated into the teaching of force and energy concepts, aiming to provide a nuanced understanding of science teachers' TPACK in action.

Moreover, the decision to concentrate on force and energy topics is motivated by the scarcity of research investigating science teachers' TPACK, particularly within the specific context of teaching these physics concepts. Despite the growing body of TPACK studies, there remains a notable gap when it comes to understanding how teachers navigate TPACK challenges when addressing force and energy topics. This dearth of research makes the exploration of science teachers' TPACK in the context of force and energy topics a valuable and pioneering area of investigation.

Furthermore, existing research in the realm of TPACK studies has predominantly focused on biology and chemistry topics, leaving physics topics comparatively understudied (Setiawan et al., 2019). This study seeks to address this gap by contributing valuable insights into science teachers' TPACK, with a specific emphasis on the unique challenges and opportunities presented by the force and energy topics in physics. In doing so, the research aims to enhance the current TPACK literature by providing specific insights and practical guidance for teachers dealing with the complexities of teaching force and energy concepts.

3.5. Context of the Study

As mentioned in the previous section, the participants in the study were science teachers from the same public middle school in a city located in Southeast Anatolian Region of Türkiye. Selecting teachers from the same school ensured that their TPACK was assessed under similar contextual conditions. This approach eliminated potential scenarios that could arise from variations in contextual characteristics among different schools in assessing and understanding their TPACK.



Figure 5. The classroom layout during observations in each classroom

The school, which included participant teachers were observed and interviewed in the study, was a public secondary school covering 16 classrooms and employing 40

teachers. This school served a diverse student population, comprising over 600 students across the 5th, 6th, 7th, and 8th grades. Additionally, the school was equipped with a dedicated IT classroom, which helps in attaining basic skills regarding information technologies. Moreover, all classrooms of the schools were equipped with smart boards and benefitted from a high-speed fiber internet connection.

Each classroom in which observations took place was equipped with ICT tools such as operational smart boards, stable internet connection, and speakers. Figure 5 provides a visual representation of each classroom's setup and the researcher's location. The observations revealed that teachers effectively utilized ICT tools in their lessons, with active student participation indicating an authentic classroom context captured during observations, as confirmed by teacher feedback.

The classroom populations varied from day to day due to student medical reports or other reasons. However, the typical class size ranged from 25 to 27 students for most teachers. In particular, Asaf's classes had 23 to 30 students, Bora's classes had 28 to 30 students, Cenk's classes had 22 to 30 students, and Esin's classes had 25 to 28 students.

3.6. Data Collection Tools

Given the aims to understand the nature of TPACK as well as assessing TPACK proficiency, it was challenging to capture these purposes with a single source of data. Consequently, different types of data collection tools were utilized to gather information from the participants related to the research questions of the study, as multiple data collection tools enabled a detailed assessment and exploration of in-service science teachers' TPACK. The instruments employed in this study included interviews and in-class nonparticipant observations of their teaching. The data collection process spanned over nine weeks.

3.6.1. Interviews

Merriam and Tisdell (2016) and Patton (2015) highlight the essential aspects of research interviews, emphasizing the importance of their types, structure, schedules, the value of pilot interviews, and recording methods. The purpose of the interviews

conducted after the teaching practices was to provide valuable insights into those research objectives, as interviews could provide in-depth information on how teachers integrated technology into their teaching, especially in aspects of understanding and assessing students, planning and designing, and practical teaching in their classes.

A semi-structured interview protocol consisting eighteen main questions was prepared to elicit in-service science teachers' TPACK-P. The interview questions were crafted to not only probe into how and why teachers utilized ICT tools but also to explore their proficiency levels in terms of understanding and assessing, planning and designing, and practical teaching aspects in their classes. These questions, primarily derived from earlier studies on TPACK-P, specifically the work of Yeh and the colleagues (2014, 2015a, 2015b), were strategically designed to probe into the nature of interplay among teachers' knowledge of all five components of the TPACK-P framework.

To ensure the interview questions were clear and linguistically sound, an expert in Turkish language education reviewed and provided language corrections. After this review, revisions and corrections were made to enhance clarity. Additionally, feedback was sought from one expert in the field of TPACK studies, especially in science education, to refine the interview protocol further. Incorporating their suggestions, adjustments were made accordingly. The final semi-structured interview protocol, as outlined in Appendix C, consisted of 18 questions categorized into three domains: learners and assessment, planning and designing, and teaching practices. This comprehensive interview guide was designed to capture detailed information regarding teachers' proficiency levels as well as the nature of the interactions among TPACK-P components.

The semi-structured format of the interview protocol allowed for a balance between predefined questions and open-ended inquiry. For instance, in the domain of 'understanding and assessing students', a core question was, 'How does using ICT tools help you in identifying the difficulties students experience in learning a particular science topic?' In the 'planning and designing' domain, a fundamental question was, 'How do you plan a lesson in which you use ICT tools?' Finally, in the 'teaching practices' domain, participants were asked a key question like, 'How using ICT tools when teaching a specific science topic affects your students' learning performance?'

Beyond these core questions, the researcher posed probe questions designed to encourage in-depth responses and provide participants with an opportunity to elaborate on their practices and beliefs. The probe questions were flexible and allowed participants to express their thoughts, experiences, and unique perspectives. By offering this semi-structured approach, the interviews allowed for consistency across the core topics while also capturing the richness of participants' insights and experiences.

During the pilot study, this interview protocol was conducted to evaluate and refine the interview process. During these pilot interview, a few issues were identified. To illustrate, the participant teacher stated some of questions were quite similar during the interview. In response to this, the interview questions were carefully reviewed again, and necessary adjustments were made to overcome such redundancy. Additionally, it became evident that the participant's familiarity with the teaching topic influenced his responses during the pilot interview. Specifically, the interviewee had some difficulties recalling what and how they planned, designed, and enacted when teaching force and energy topics, as the interviews were conducted prior to teaching those subjects. Consequently, the researcher decided that interviews should take place after the researcher's observations of teaching, allowing participants to provide more accurate and detailed information about their teaching designs and plans. Thus, piloting the interview protocol provided a great contribution to refining the interview process, ensuring that it aligns more effectively with the study's objectives and facilitates the collection of valuable insights from the participants.

Finally, interview sessions were conducted face-to-face with each participant and audio-recorded to facilitate transcription into text for data analysis. The duration of each interview varied, with Asaf's interview lasting 87 minutes with one coffee break, Bora's interview lasting 102 minutes with one tea break, Cenk's interview lasting 63 minutes with two breaks to change the location, and Esin's interview lasting 68 minutes with one coffee break.

3.6.2. Observations

To facilitate the observation for this study, careful planning and considerations were undertaken, aligning with the guidance of Merriam and Tisdell (2016). This process involved gaining access to the observation sites, obtaining necessary approvals,

familiarizing the researcher with the settings, defining the scope of observations, specifying the researcher's (observer) role, and determining the focus and tools for effective data collection.

Prior to data collection, a crucial preparatory step involved familiarizing the researcher with the classroom and school settings. This was necessary to understand the physical layout, seating arrangements, and the availability of ICT resources. Acquiring this contextual knowledge enabled the researcher to plan effective camera placement for video recording.

As a nonparticipant observer (or complete observer), the researcher's role was strictly limited to observing and recording classroom activities. The researcher refrained from direct interaction with both students and the teacher to maintain an unobtrusive presence and minimize potential influence on the teaching process. The primary focus of observations was to capture instances of technology integration within the context of teaching force and energy topics. Specifically, the observations aimed to record how ICT tools were employed for understanding and assessing students, planning and designing lessons, and executing teaching performance. However, the observations were made in a holistic manner. These aspects were highly intertwined and might be challenging to distinguish during the observation, which justified the use of video recording.

To ensure systematic data collection, an observation protocol was devised (Appendix A). This protocol outlined key elements to be recorded during observations, including the topic being taught, the date of observation, the name of classroom, the teacher pseudonym, and additional details related to the physical settings. It also guided the recording of noteworthy observations related to teachers and students, such as interactions with ICT tools, technical difficulties encountered, and other subtle factors like the interpretation of symbols and the teacher's gestures and verbal statements. In the protocol, such noteworthy observations were organized into five components of TPACK-P framework as focus of the observation to align with the research objectives. The researcher did not record every detail but focused on key observations related to the research aims. These notes were time-stamped to make them easier to locate in the video recordings. Along with video

recording, the data coming from these observation protocols contributed to a more comprehensive understanding of the participants' TPACK.

In accordance with purposes of the study, the researcher was usually positioned at the back corner with camera to observe the teaching performances of each teacher. Figure 5 illustrates the positions of the researcher in the classrooms. During the transcription of the observational data, both video recordings and observation notes gathered through the observation protocol were merged carefully.

Table 4 below presents a detailed overview of observed class sessions conducted by four teachers, each focusing on specific topics related to mass, weight, force, work, and energy relations. As indicated in the table, the class sessions span from 10 to 15, highlighting the instructional activities undertaken during each session. For example,

Asaf predominantly emphasized Mass and Weight Relations in various sessions, incorporating both content acquisition and assessment activities. Bora similarly covered Mass and Weight Relations in early sessions and then delved into Force, Work, and Energy Relations, with a concluding session involving a comprehensive review of all topics. Cenk's sessions exhibited a mix of Mass and Weight Relations and Force, Work, and Energy Relations, culminating in a session that wrapped up all topics. Esin's classes covered a range of topics, with a greater emphasis on Energy Transformations, and a concluding session involving both a wrap-up of all topics and a comprehensive assessment. The key provided at the end of the table clarifies the abbreviations used: CA for Content Acquisition, where instructional emphasis is placed on acquiring content, and AA stands for Assessment Activities, where activities involve assessing aspects of student understanding. Furthermore, italicized entries represent the related topics in the force and energy unit. This comprehensive table offers insights into the instructional focus and activities undertaken by each teacher throughout the observed class sessions, providing valuable context for understanding their teaching approaches.

3.7. Data Analysis

As outlined by Merriam and Tisdell (2016), the data analysis should involve a systematic process for managing and organizing the collected data, which includes transcribed interviews, observations, and other data sources. This enables readers to comprehend the data analysis process through a step-by-step explanation. Surely, it is important to emphasize that it is important to emphasize that qualitative data analysis is more flexible and evolving compared to quantitative data analysis (Merriam & Tisdell, 2016). Additionally, the qualitative data analysis method elucidates the employment of the constant comparative method, which serves to clarify the inductive and comparative analysis strategy and is supported by appropriate references.

Although there is no single standard method for data analysis in qualitative research, Creswell (2009) identifies several steps in reporting the data analysis procedure. This process began by transcribing all audio recordings (interview data) and video recordings as well as observation notes (observation data) into electronic formats by the researcher. The next step involved thoroughly reading and rereading all the data to gain a comprehensive understanding of the information. For this reason, the researcher read the all transcriptions repeatedly, and returned to recordings and retyped them if the transitions seemed to unclear.

Following this, the third step was the coding process. During this phase, the transcribed data in forms of words, clauses, sentences, or paragraphs were divided into data points, which were identified as codes. For coding process, the researcher can (1) improve codes based only on the emergence of information gathered from participants (inductive content analysis), (2) use predetermined codes and then adapt the data to them (deductive content analysis), or (3) use the integration of predetermined codes with new codes (combined approach). This study utilized both deductive content analysis and combined approach.

For the first purpose of this study, which was exploring the proficiency levels of science teacher's TPACK-P, a deductive content analysis strategy was used to explore participants' TPACK proficiency. These predetermined codes (categories) were namely assessment, planning and designing, and enactment. Based on the content of the data and referring to TPACK-P components, several subcategories were emerged

in the coding process. For example, the code ‘verbal and visual instruction’ was categorized under the ‘ICT guidance’ subcategory within the ‘Enactment’ category. Detailed information about these codes, subcategories, and categories as well as their descriptions can be found in the coding table in Appendix D.

On the other hand, a combined approach was employed in the coding process for the second purpose of the study, which was investigating the nature of the interplay among TPACK-P components. In this approach, the analysis of interviews and observations was first labeled under predetermined codes (categories) sourced from the components of TPACK-P framework, which are namely knowledge of assessment (KoA), knowledge of learners (KoL), knowledge of subject content (KoSC), knowledge of curriculum design (KoCD), and knowledge of practices in teaching (KoPiT). Some of these categories were further divided into subcategories due to content of the data and generation of new codes. For instance, the ‘animation’ code was categorized under the ‘ICT representation used in teaching’ subcategory within the ‘KoCD’ category. Although KoCD was a predetermined category, animation code was emerged from the data, and this code and similar codes were categorized under the ICT representations used in teaching. Detailed information about these codes, subcategories, and categories as well as their descriptions can be found in the coding table (Appendix E).

The fourth step involved creating patterns or themes for analysis. For the first research objective, this meant assessing the proficiency levels of participants, while for the second objective, it required identifying potential interplays among TPACK-P components. The findings were used to create TPACK maps for each teacher. These maps were collectively examined to formulate themes or assertions.

In the fifth step of data analysis, narrative passages were used to convey the findings. These narratives consisted of direct quotations from teachers’ statements in the interviews and written descriptions of observation segments.

In the final step of data analysis, the researcher interpreted the findings with the support of related theoretical frameworks and perspectives. This step facilitated the discussion of similarities and differences in the findings, along with comparisons to earlier research findings ultimately leading to well-informed and meaningful conclusions, which are crucial for drawing significant insights from the study.

3.7.1. Data Analysis for TPACK Proficiency Levels

Concerning the analysis of the first research question in the study, the proficiency levels of TPACK among in-service science teachers were examined based on data derived from interviews and observations of instructions as illustrated in Figure 6. Prior to determining these levels, a deductive coding process was employed to find and organize all the essential evidence necessary for the evaluation.

Since the first purpose of the study was to explore TPACK-P proficiency levels of the participants, all codes belonging to each category were carefully examined and compared to determine the level of TPACK proficiency. The coding process for assessing teachers' TPACK-P proficiency levels followed several steps. The researcher provided one of the interview and observation transcripts, as well as the rubric, to the external coder for assessing teachers' proficiency levels. Both the researcher and the external coder underwent data training together first. Subsequently, they independently analyzed the transcripts of the interview and the observation, identifying data points that demonstrated evidence of proficiency levels regarding assessment, planning and designing, and enactment dimensions. They met several times to compare and discuss their independent analyses. After resolving slight discrepancies, both coders reached to a consensus to ensure a unified understanding and interpretation of the TPACK-P dimensions within the dataset. For instance, when a teacher used an ICT tool that could be evaluated as an assessment practice (such as having students solve a fill-in-the-blank question on the smart board), it was coded as an in-class formative assessment. Similarly, a multiple-choice test that a teacher conveyed to students' EBA pages through the EBA platform was coded as an out-of-class formative assessment.

In a further step, they independently scored each coding according to the rubric criteria. Importantly, when there was multiple evidence for different proficiency levels for a teacher, the researcher and the external coder determined the proficiency level based on the quality and significance of the evidence rather than relying solely on the frequency of evidence. These decisions were explained clearly in reporting findings, ensuring transparency and a comprehensive understanding of the proficiency assessment process. Thus, detailed discussions and re-evaluations resulted in a full

scoring agreement, determining each teacher's proficiency level in each educational dimension. This process allowed for the determination of each teacher's proficiency level within each educational dimension.

The rubric developed by Yeh and colleagues (2015b) was utilized in the assessment of TPACK-P proficiency levels of the science teachers. This rubric encompassed criteria within three general categories: assessment, planning and designing, and enactment, which all contributed to establishing the proficiency levels of the participants. Essentially, TPACK-P framework includes five components which are assessment, curriculum design, practical teaching, learner, and subject content. These five components are fundamental building blocks for teachers' knowledge, with their influence spanning across various dimensions. However, in the context of this study, three dimensions, specifically assessment, planning and designing, and enactment, were selected to delve deeper into teachers' TPACK-P proficiency levels. The rationale behind this was that these domains were the main areas for developing the professional knowledge of twenty-first-century teachers (National Commission on Teaching and America's Future 2003; Yeh et al., 2015a). Consequently, the rubric was constituted by four proficiency levels within three domains, and hierarchically ranked from lowest to highest as lack of use, simple adoption, infusive application, and reflective application.

Before the pilot study, expert opinions were sought to ensure that this rubric was suitable for assessing the TPACK-P proficiency of teachers. Since feedback confirmed the rubric's appropriateness, it was used without modification during the data analysis of pilot study. However, when analyzing the main study findings, both the researcher and an external coder concurred on the need for partial modification in the rubric. They observed that the rubric appeared not to address one aspect within the enactment dimension. Consequently, they recognized a lack of criteria for assessing how teachers integrated ICT tools into their instructional management. As a result, a subdimension called 'infusing ICT into the teaching context' was added under the enactment dimension in the rubric. The criteria for each proficiency levels for this subdimension were identified based on the both the structure of data and related previous studies. Moreover, most of items in the rubrics were slightly revised to improve their clarity and alignment with the data content. For example, the researcher and the external coder

agreed to replace “Uses the interactive response system (IRS) to understand students and engage student-centered, ICT-infused instruction to let students self-construct their learning” with “Teacher uses the learning management systems (LMS) to understand students and engage student-centered, ICT-infused instruction to let students self-construct their learning.” The reason of this revision was to provide a more explicit and comprehensive description of the teacher’s role in utilizing ICT-infused assessments. The second statement specifies that the teacher is actively involved in the process of using these assessments to engage students, which is clearer and more precise for evaluation purposes. It also adds clarity by emphasizing the students’ scientific thinking abilities and constructing models through technology-enhanced evaluations. Additionally, the researcher assigned labels to each criterion in the rubric to enhance comprehensibility. Thus, this adapted rubric (Appendix B) was finalized and used for data analysis for the main study.

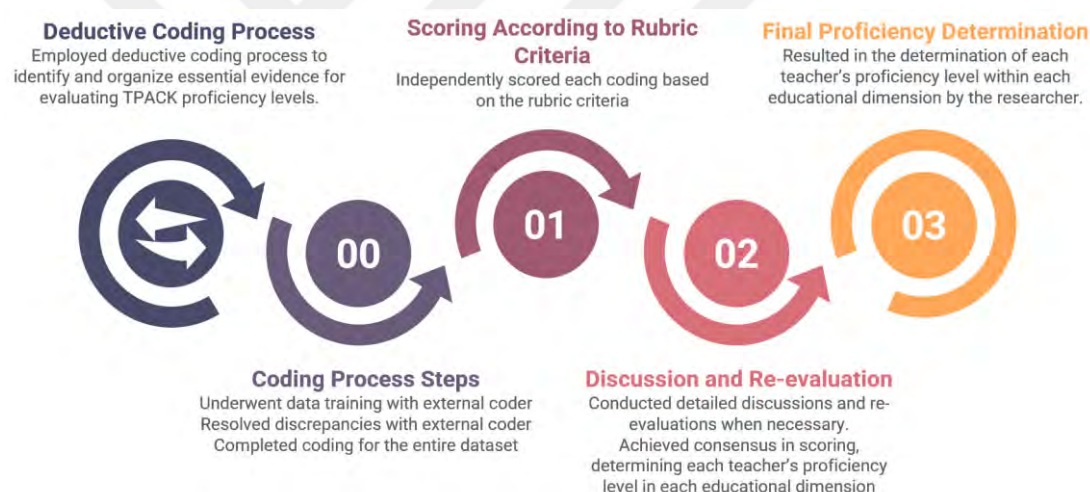


Figure 6. Data analysis overview for exploring TPACK-P proficiency levels

In the rubric, teachers’ proficiency levels in assessment category were categorized into two subcategories which are understanding students’ learning needs and assessment practices. While planning and designing domain encompasses planning the class, ICT representations, and teaching method/technique, enactment domain includes subcategories of ICT guidance, struggling with technical issues, and infusing ICTs into teaching contexts. Proficiency levels define the different levels of proficiency within each subcategory, ranging from lack of use to reflective application. These proficiency levels are associated with descriptive explanations to clarify what each level entails to

make it easier for the reader to understand the criteria for assessment. Thus, the rubric provides a comprehensive framework for evaluating and understanding teachers' TPACK-P proficiency levels.

3.7.2. Data Analysis for Interactions among TPACK Components

The second research question of the study, involving the exploration of the interplay among TPACK-P components, was addressed by examining the interactions among these components. As shown in Figure 8, the brief data analysis diagram illustrates the dynamic relationships and connections observed throughout both the coding and broader data analysis processes. During the coding process, both the external coder and the researcher actively participated. Before data coding training started, the researcher provided a comprehensive guideline with operational definitions for each TPACK-P component, including explanations for potential interactions (Table 5).

To ensure coding consistency, independent coding was initially performed on one interview and one observation dataset. Initially, codes belonging to each TPACK-P component were identified without considering potential interplay. During this process, both coders sometimes met to compare their codes. While they concurred on most codes, slight discrepancies were emerged. The researcher and external coder collaborated to reach a shared understanding. Following this, the researcher coded all the remaining data.

Similar cooperation was made during identifying TPACK-P episodes with the external coder. They scrutinized these codes from one interview and one observation dataset to identify TPACK episodes referring that intersection of at least two different TPACK-P components. Later, they observed significantly fewer differences compared to the initial coding. his collaborative effort resulted in a substantial reduction in discrepancies from the initial coding stage, facilitating the identification of potential interactions among TPACK components within each episode. Following their attainment of complete agreement, the researcher proceeded to identify all TPACK-P episodes for the remaining data, streamlining the analysis process. The detailed overview of these data analysis steps is depicted in Figure 8, providing transparency and clarity regarding the methodology employed.

Table 5. The names and definitions of each interplay

Name of Interplay	Definition
KoCD-KoA	involves strategically integrating technology into science lessons through the selection of ICT representations and teaching techniques aligned with curriculum objectives. It also encompasses using ICT for assessing students' progress, employing various assessment methods, and understanding the role of technology in science class assessments.
KoCD-KoPiT	refers how explicitly teacher guides and engages their students in ICT-infused learning that is planned to use appropriate ICT representations, teaching strategies, and learning activities in accordance with science curriculum
KoCD-KoL	refers to taking into consideration of students' cognitive development, learning difficulties, learning preferences when designing and planning ICT-based science class in terms of utilizing appropriate ICT representations, teaching strategies, and learning activities in accordance with science curriculum.
KoCD-KoSC	requires a deliberate selection of ICT representations, teaching techniques, and learning activities in harmony with science curriculum objectives, while leveraging expertise in using ICT to effectively deliver challenging science content and enhance comprehension.
KoPiT-KoA	involves teachers' knowledge in addressing challenges related to ICT use, their instructional management skills tailored to student needs, and their ability to guide students effectively in using technology for learning when utilizing technology for designing and conducting science assessments.
KoPiT-KoL	refers to taking into consideration of students' cognitive development, learning difficulties, learning preferences when applying both instructional management skills and infusing ICT into teaching context effectively.
KoPiT-KoSC	involves integrating pedagogical expertise for technology-enhanced science lessons, effectively leveraging ICT to deliver challenging science content. This includes addressing ICT challenges, guiding student ICT use, and skillfully managing the instructional process to facilitate a deeper understanding of science topics.
KoA-KoSC	involves the effective utilization of appropriate formative assessment strategies in conjunction with ICT tools, considering the alignment and appropriateness of subject content delivered with ICT. This interplay involves assessing student understanding and progress during the learning process, ensuring that the chosen ICT tools enhance the clarity and comprehension of subject content.
KoL-KoA	refers to the dynamic interaction between a teacher's understanding of their students' cognitive development, learning difficulties, learning preferences, and background knowledge, all in the context of utilizing ICT-based formative assessments. This interplay involves teachers using their knowledge of students to design and implement effective assessment strategies that align with students' unique characteristics and needs.
KoL-KoSC	involves strategically leveraging technology to diagnose students' learning difficulties, misconceptions, learning styles, background knowledge, and motivational needs, thereby enhancing their understanding by considering the alignment and appropriateness of subject content delivered with ICT.

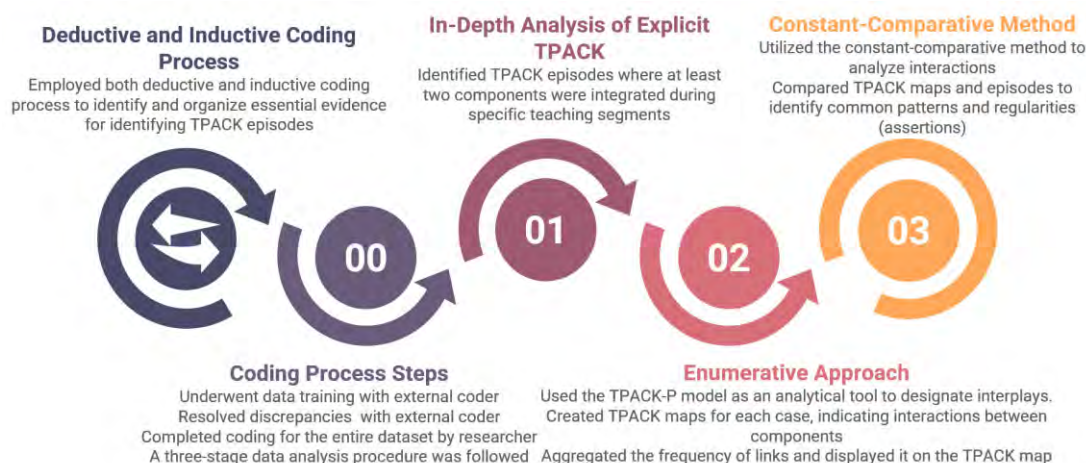


Figure 7. Data analysis overview for exploring the nature of interplay among TPACK-P components

3.7.2.1. In-Depth Analysis of Explicit TPACK

The in-depth analysis (Park & Chen, 2012) of explicit TPACK aimed to identify components integrated into participants' TPACK during specific teaching segments. These teaching segments were defined as instances where at least two TPACK components from the TPACK-P framework were integrated. These segments were labeled as TPACK episodes, providing evidence regarding the use of ICT tools or ICT-based teaching processes within the TPACK-P framework. For instance, a teacher might decide to use an animation on the smart board when students struggle to comprehend the concept of Earth's gravity from images or verbal explanations. This demonstrates a one-way interaction between KoL and KoCD. In some cases, these interactions could occur at different times between two or more knowledge components, creating a two-way interaction. That is, if KoL informs KoCD in one instance, and KoCD informs KoL in another instance, then this interaction was considered as a two-way interaction.

3.7.2.2. Enumerative Approach

To clearly designate interplays among TPACK components, an enumerative approach (LeCompte & Preissle, 1993) was employed following the in-depth analysis of explicit TPACK and the identification of TPACK episodes. Interactions among TPACK components were indicated using the TPACK-P model as an analytical tool, defined

as a TPACK-P map. Each TPACK-P map assumed there was at least one connection between any two components, represented as links with a strength of “1” between components on the map. Each link was considered to have the same strength of 1, similar to the approach used by Park and Chen (2012).

This procedure was applied to all TPACK episodes. The frequency of all links between any two TPACK components was aggregated across all episodes and displayed on the TPACK-P map. Additionally, the numbers within each TPACK component represented the total interactions of that component, while the numbers next to lines indicated the number of interactions between two components. The power of the interactions depended on the frequency of links, with stronger links indicating higher interaction frequency.

To illustrate better, the map depicted in the Figure 8 shows six TPACK episodes are interconnected between KoA and KoL. Additionally, three TPACK episodes connect KoA and KoCD. The more interactions among TPACK components a teacher had, the thicker lines appear on the TPACK map. Accordingly, the strength of interactions depends on the frequency of these connections. Thus, if there is a high frequency between components, the links become stronger. Furthermore, the total interactions for each knowledge dimension are indicated within the respective circle of that knowledge.

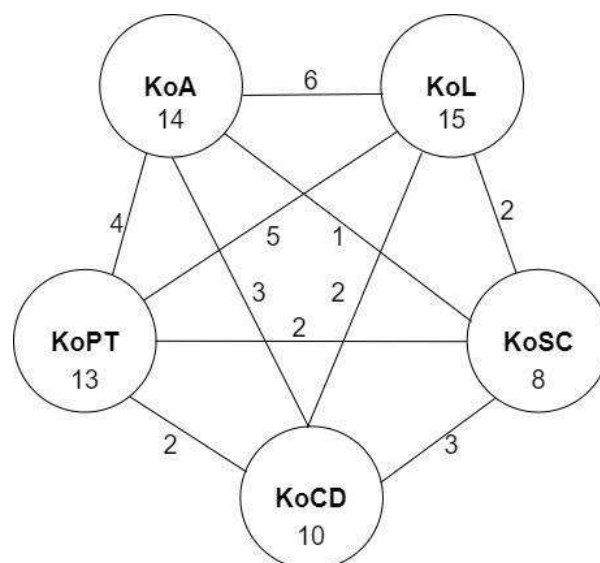


Figure 8. A sample TPACK map

3.7.2.3. Constant-Comparative Method

After identifying all TPACK episodes and constructing the TPACK map, the constant-comparative method (Glaser & Strauss, 1967) was utilized as the final step in analyzing interactions among TPACK components. This approach facilitated the discovery of common patterns and regularities among TPACK components without relying on pre-established categories or frameworks, making it an inductive and comparative data analysis process. In this method, TPACK maps and the related TPACK episodes were compared to each other by to determine similarities and differences, allowing for the categorization of these episodes. This process enabled the identification of several assertions regarding the nature of in-service science teachers' TPACK, which is the second objective of this study.

3.8. The Pilot Study

Before beginning to a case study, implementing a pilot case study usually provides considerable insights for researchers to reconsider the data collection plans. Moreover, issues that arose during the pilot study shed light on necessary revisions as noted by Yin (2015). As a result, the pilot case study allowed for a review of the questions in the interview protocol, classroom observation procedures, and other data collection plans.

An experienced science teacher at a public middle school was chosen based on the study's participation selection criteria mentioned in selection of the participants section (Sect. 3.3). Prior to initiating data collection, the teacher was informed about the examination of their teaching of force and energy topics in seventh-grade classes. Following the acquisition of the teachers and school administration's permission, along with other necessary permits, an interview was conducted before the teaching of force and energy topics. Subsequently, 12 class hours of observations were carried out, recorded with video equipment placed in the corner of the classroom. Additionally, an attempt was made to access documents related to the teacher's class and course planning. The classroom setting was consistent with the standard public-school setup, equipped with a smart board and an internet connection. The classroom environment and teaching methods closely mirrored those in the main study. During the interview, several points were identified as potentially problematic. To begin with, the interview

protocol consisted of twenty-one questions, and its completion took longer than expected, lasting 95 minutes. The teacher also requested a break to have coffee and rest. After a ten-minute break, the interview resumed. However, the teacher encountered difficulty in responding to two questions related to practical teaching, despite attempts to clarify the questions. Recognizing the challenges posed by these specific questions and aiming for a more streamlined and effective interview process, a revision of the interview protocol was undertaken. This involved merging similar questions, eliminating redundant ones, and refining the wording of the problematic questions, guided by expert opinions. These adjustments were implemented to enhance the overall coherence and efficiency of the interview, ensuring that the questions align more seamlessly with the study objectives. Additionally, it was observed that interviewing the teacher two weeks prior to commencing teaching made it challenging for the teacher to recall his plans for teaching. This suggested that the teacher had either not yet formulated plans for this topic or was struggling to recall the plans due to concurrent teaching of a different topic. Consequently, the decision was made to conduct the interview after the teaching observations were completed, as this would likely result in more comprehensive insights into the design and planning of lessons.

After completing the fieldwork, preliminary analysis was initiated. The science teacher's TPACK-P proficiency level was primarily assessed using the rubric developed by Yeh et al. (2015b). Upon transcribing the interview and observations, the transcriptions were reviewed for any necessary adaptations or additions to the rubric. After careful examination, the researcher decided that no revisions were needed. Therefore, the rubric, consisting of four proficiency levels (lack of use, simple adoption, infusive application, and reflective application) across three instructional scenarios (assessment, planning and designing, and enactment), encompassing seven subdimensions, was deemed suitable for use in the main study.

Preceding the pilot study, there was an initial plan to collect data from teachers' documents, such as lesson plans or teacher's notes. However, observations and interviews with the teacher revealed that, according to the participant teacher's own statements and the researcher's further investigations, a significant number of teachers in public schools may not be consistently preparing daily lesson plans. Moreover, it became evident that, based on the available information, there were no teacher

documents accessible that could consistently provide insights into the participant teacher's TPACK. Consequently, the analysis of documents was excluded from the data collection tools for the main study.

Overall, the pilot case study proved beneficial in several ways. Beyond testing the data collection methods, it aided in the validation of participant selection criteria. This involved visiting multiple schools to identify a suitable participant, which not only helped determine which teacher was suitable for the study but also provided insights into teachers' willingness to volunteer, the availability of technology facilities, classroom conditions, and the feasibility of data collection, such as ensuring an empty chair in the classroom and stable internet connection. Another crucial lesson from the pilot study was the realization that in-class observations with video recording could be considered risky for both the teacher and students. At the beginning of the observations, the teacher introduced the researcher to the entire class and assured students that only the teacher's actions on the smart board would be recorded, not those of the students. After the observation of his first class, the students appeared to be more comfortable. During class breaks, the teacher was asked about whether he or his students felt any pressure or discomfort due to the researcher's presence. The teacher reported that he had spoken with several students from the class, and none expressed any negative feelings or behaviors regarding the observer's presence. Consequently, it was determined that the observer's presence did not impact the teacher's performance or the students' reactions during the observations.

3.9. Trustworthiness of the Study

Whatever the research design, ensuring validity and reliability can be achieved by meticulously considering how the study is conceived, how data is collected, processed, and analyzed, and how the findings are reported. Qualitative research also contains methods for determining the veracity and trustworthiness of a study; these methods are founded on worldviews and inquiries consistent with the philosophical presuppositions behind this perspective. To ensure trustworthiness in constructivist qualitative research, there are certain issues that need to be addressed in addition to paying attention to ethical issues. Merriam and Tisdell (2016) labelled these 'credibility' for internal validity, 'consistency' for reliability, and 'transferability' for external validity

based on terminology introduced by Lincoln and Guba (1985).

3.9.1. Credibility

The answers to the questions how well research findings accord with reality and how closely do the results match the facts are the subject of credibility. Because people are the main source of data for qualitative research, their observations and interviews provide direct access to how people interpret the world. Although qualitative researchers can never fully capture an objective reality, there are a number of techniques you can employ as a qualitative researcher to raise the credibility of the results as follows:

- **Triangulation of data sources:** to further enhance credibility, researchers can employ the technique of triangulation, which involves collecting data from multiple sources and subsequently making comparisons. In this study, data were carefully gathered through both observations and interviews to diversify the sources and to ensure a comprehensive exploration of the research questions.
- **Member check (respondent validation):** this involves sharing research findings, including detailed transcripts of participants' statements and teaching performances, with the study participants to seek their feedback and validation. In this study, a very brief summary of emerging research findings as well as comprehensive transcripts of participants' interview statements and teaching performances were shared with each participating teacher. Having asked to their thoughts, all of them agreed with their accuracy and representation. This process of feedback and validation played a crucial role in contributing to the credibility of the research outcomes.
- **Adequate time spent (prolonged engagement):** one way to make qualitative research more trustworthy is by spending enough time on it. This helps researcher really understand the people that are studied, their culture, language, and what they think. In this study, data collection spanned an extensive period, encompassing about three months. This timeframe included about two months for the pilot study, and about three months for the main study. Throughout this duration, both pilot and main study observations and interviews were conducted. The extended engagement

for each phase of the study allowed for a comprehensive exploration of participants' experiences, contributing to the depth and richness of the study's findings.

- **Reflexivity (researcher's position):** this reflects researchers' self-acknowledging about their background, expectations, theoretical orientations, or assumptions that potentially influence the research processes, especially in shaping the interpretation of findings. Consequently, it is crucial to address various aspects related to the researcher's position throughout the study. Initially, the researcher collected all data as nonparticipant observer during the classroom observations. Along with video recording of the smart boards, the researcher took necessary notes in the observation protocol to capture important moments potentially reflecting teachers' TPACK or the reactions of teachers and students that were not recorded by the camera. This data collection approach ensured that crucial evidence for the research purposes was not overlooked. This approach demonstrates the researcher's commitment to thorough data collection and the recognition that valuable insights can emerge from unrecorded interactions. Secondly, the researcher spent abundant time in the school environment, particularly in teachers' room, the classrooms, and school corridors. This extended presence allowed the researcher to become acquainted not only with the participant teachers but also with their students. By assimilating into the daily routine of each classroom and the school community, the researcher established a sense of belonging and comfort among all members, which facilitated the collection of essential data within the authentic context and contributed to the acquisition of more realistic data. This emphasizes the researcher's commitment to fully engaging with the research environment, establishing trust with participants and gathering data within a genuine and real-life setting. Thirdly, the researcher held the belief that assessing a teacher's TPACK heavily relies on observing their teaching performance, with the primary evidence of their TPACK being derived from their classroom practices. Finally, the researcher's focus was on technology-related or ICT-related instances, statements, or actions when identifying evidence related to teachers' TPACK. However, this narrow focus could potentially result in the omission of outstanding features of teachers' pedagogical skills that do not involve technology use. For instance, a teacher's remarkable pedagogical skill, such as using analogies to explain complex scientific concepts without technology, might not receive the recognition it deserves in the assessment of TPACK. In summary,

these aspects collectively exemplify the researcher's reflexivity and the continuous self-awareness that informed various decisions and actions throughout the research, ultimately contributing to the depth and richness of the study.

- **Peer examination (peer debriefing):** additionally, peer debriefing was carried out to enhance objectivity. Feedback related to whole research steps was obtained not only from the researcher's supervisor but also from the thesis monitoring committee, comprising colleagues who provided valuable insights and perspectives on the research process. Moreover, the interview questions were sent to an expert colleague in TPACK studies to ensure their relevance and effectiveness in eliciting valuable responses from participants. Furthermore, the peer debriefing utilized in the process of creating codes and categories and in scoring TPACK-P competencies also contributed to obtaining more reliable results. Thus, the insights gained through peer debriefing positively influenced the research process and findings.
- **Back translation:** furthermore, there is another point in ensuring the credibility of this study. To translate participants' responses accurately from Turkish to English when presenting findings, a meticulous translation process was followed. Following Merriam and Tisdell's (2016) recommendation, a back translation strategy was incorporated. In this process, the translated statements of participants were translated back into the Turkish. The close alignment between the back-translated version and the original responses serves as a check on the accuracy of the translations. This methodological step adds a layer of assurance to the reliability of the translations, contributing to the overall credibility of the research outcomes.

3.9.2. Consistency

Consistency, also expressed by terms such as reliability and dependability, essentially refers to the repeatability of research results in traditional terms. In qualitative research, the primary focus for consistency is whether the obtained results align with the collected data. Achieving this involves strategies such as triangulation, peer examination, researcher's reflexivity, and the audit trail (Merriam & Tisdell, 2016). The previous section covers the first three strategies in detail.

- **Audit trail:** Merriam and Tisdell (2016, p.251) defined audit trail as detail

information on “how data were collected, how categories were derived, and how decisions were made throughout the inquiry.” Throughout this study, intense documentation was maintained to enhance transparency and trustworthiness. This comprehensive documentation began with a detailed exposition in the method chapter, which outlines the study’s design, participant selection criteria, and provides comprehensive descriptions of the data collection tools. It also elaborated on the contextual details of the study’s location and data collection site.

3.9.3. Transferability

Various strategies can be used to increase the likelihood of transferring the results of a qualitative study to another setting. Since readers should clearly see how current study’s context resemble to theirs, selection of participants and detailed information about the findings should be explicitly given (Merriam & Tisdell, 2016). By selecting teachers purposefully within their specific contexts, it becomes possible to establish commonalities that may extend to similar schools or teachers. This deliberate selection process enhances the study’s findings’ applicability and can aid readers in making meaningful comparisons with their own situations. Moreover, rich, thick descriptions were provided to enhance the transferability of the findings to support transferability. These descriptions enable readers to assess the potential relevance and applicability of the findings to similar settings or situations.

3.10. Ethical Considerations

According to Merriam and Tisdell (2016), ethical considerations in qualitative research are integral to ensuring the trustworthiness of the study. Researchers must demonstrate credibility, intellectual rigor, and ethical competence throughout the research process, from data collection to reporting findings. Thus, the researcher is committed to upholding ethical responsibilities, encompassing both ethical behavior and principled decision-making to establish a strong ethical foundation and enhance the study’s credibility.

Initially, the researcher obtained necessary permissions for the pilot study and the main study separately. This was necessary due to the extended time span between them, caused by the COVID-19 pandemic, which hindered face-to-face education. Ethical

approval for the main study was granted by the Research Center for Applied Ethics of Middle East Technical University (Appendix F). Following approval from this department, a similar process was undertaken with the Provincial Directorate for the National Ministry of Education since the data collection occurred in public middle schools (Appendix G).

As explained in detail in the participant selection section, the researcher visited candidate schools to meet the school administration and teachers. During these visits, the researcher briefly explained the research's content and purposes, emphasizing voluntary participation to both administrators and teachers. Specifically, all purposefully selected participants were invited to take part in the study and signed the Informed Consent Form (Appendix H). In cases where camera recording was involved, each teacher was asked once more if they experienced any disturbances during their classroom teaching. All participants confirmed that they felt comfortable with the camera inside the classroom and that it did not affect their teaching. Moreover, the researcher informed them they might choose to withdraw from the study at any time.

Additionally, the researcher aimed to establish trust with each participant by guaranteeing the confidentiality of video recordings, audio recordings, and their personal information. It was emphasized to the participants that this information would never be disclosed to anyone except the researcher for data analysis. To maintain this confidentiality, all files related to audio and video recordings were securely stored on an external hard drive with password protection. Furthermore, all teachers were assigned pseudonyms by the researcher.

During the data analysis phase, the researcher focused on accurately reflecting participants' own statements and actions rather than imposing personal interpretations. Seeking intercoder agreement helped reduce researcher bias and facilitate a more objective exploration of the data. Additionally, incorporating narratives and supporting visuals demonstrated the commitment to interpreting data as objectively as possible.

Throughout the research, from data collection to reporting findings, the researcher remained firmly committed to upholding ethical responsibilities. Ultimately, ethical considerations in this study reflected the researcher's dedication to conducting research with integrity, recognizing its profound impact on research outcomes.

CHAPTER 4

RESULTS

This section presents the findings obtained to answer the research questions in this study. The research questions are summarized as follows:

- What are the proficiency levels of in-service science teachers' TPACK-P in teaching force and energy topics?
- What is the nature of interplay among the five TPACK-P components of in-service science teachers in teaching force and energy topics?

The study findings were presented in two main sections, which corresponded to the research questions. As explained in data analysis section of the method chapter, the first section delved into the participants' proficiency levels in the three domains of the TPACK-P framework, offering a thorough analysis based on class observations and interviews. In the second section, the analyses explored how the TPACK-P components within each case interacted with each other. This structure facilitated a comprehensive exploration of the participants' proficiency levels and the dynamics among the TPACK-P components.

4.1. TPACK-P Proficiency Levels of In-service Science Teachers

Observation data served as the primary source for evaluating the proficiency levels of in-service science teachers. This data, which was collected through classroom observations, offered direct insights into teachers' actual instructional practices. Complementing the observational data, interview data was also integrated into the analysis. The combination of both data sources offered valuable insights into actual teaching practices and underwent deductive content analysis. This facilitated a more comprehensive understanding of proficiency levels and provided rich insights.

As the TPACK-P framework encompasses three educational dimensions to assess

proficiency levels, namely assessment, planning and designing, and enactment, the proficiency levels of the teachers were reported accordingly. Table 6 presents the TPACK proficiency levels for each teacher corresponding to educational dimensions.

Table 6. Teacher's TPACK-P proficiency levels according to three educational dimensions and their subdimensions

Name of the subdimension/dimension	Teachers' proficiency level in each dimension/subdimension			
	ASAF	BORA	CENK	ESIN
Understanding Students' Learning Needs	simple adoption	simple adoption	simple adoption	infusive application
Assessment Practices	simple adoption	simple adoption	infusive application	infusive application
ASSESSMENT	simple adoption	simple adoption	simple adoption	infusive application
Planning the Class	simple adoption	lack of use	infusive application	reflective application
ICT Representations	simple adoption	simple adoption	infusive application	infusive application
Teaching Method/Technique	simple adoption	lack of use	simple adoption	infusive application
PLANNING AND DESIGNING	simple adoption	lack of use	infusive application	infusive application
ICT Guidance	simple adoption	lack of use	infusive application	infusive application
Struggling with Technical Issues	simple adoption	infusive application	simple adoption	reflective application
Infusing ICTs into Teaching Contexts	infusive application	simple adoption	infusive application	infusive application
ENACTMENT	simple adoption	simple adoption	infusive application	infusive application

The Table 6 presents an overview of the TPACK-P proficiency levels of four in-service science teachers, namely Asaf, Bora, Cenk, and Esin. The analysis was organized into three educational dimensions: Assessment, Planning and Designing, and Enactment. Each dimension was further divided into subdimensions that correspond to specific aspects of teaching with technology. The proficiency levels for each teacher were classified according to the following scale: lack of use, simple adoption, infusive application, and reflective application. The subdimensions under each educational dimension help capture the varying degrees of proficiency and

utilization of ICT in different aspects of teaching. For the assessment dimension, these subdimensions focus on *understanding students' learning needs* and *assessment practices*. In Planning and Designing, the subdimensions cover *planning the class*, *ICT representations*, and *teaching methods/techniques*. Lastly, the Enactment dimension includes subdimensions such as *ICT guidance*, *struggling with technical issues*, and *infusing ICTs into teaching contexts*. When examining the table, it becomes evident that the proficiency levels of each teacher within each dimension vary. These levels range from a lack of use, such as in Bora's planning and designing, to infusive application, as seen in Cenk's and Esin's enactment. However, it is notable that none of the teachers reached the highest level (reflective application) in any dimension.

The subcategories and codes provided under the category of assessment demonstrate a reasonable framework for analyzing different aspects of assessment practices that incorporate ICT tools. These subcategories effectively capture varying levels of proficiency and utilization of ICT in assessing student learning needs and implementing assessment practices. Under the subcategory *understanding student learning needs*, different levels of ICT proficiency are represented, ranging from being unable to use ICT effectively to using basic ICT tools. Additionally, the subcategories focus on observing students' ICT interactions and utilizing a LMS for understanding and structuring self-learning. Regarding *assessment practices* subcategory, it highlights the use of ICT in assessment, including no use of ICT, using ICT for in-class and out-of-class formative assessment, and employing comprehensive ICT tools for enabling product/model design as an assessment practice.

In terms of TPACK-P proficiency in planning and designing according to TPACK-P framework, three subcategories were identified within the planning and designing category. The emergence of these subcategories was determined through a thorough examination and coding of the data. These subcategories, namely planning the class, representations, and teaching methods, effectively encompass various aspects of planning class activities, utilizing representations, and employing teaching methods in the context of ICT integration in science education. Under *planning the class* subcategory, the codes encompass various levels of ICT integration such as non-ICT goal setting, utilization of ICT tools to support teaching, and the incorporation of multiple ICTs to enhance both science concept learning and learning about science.

These subcategories highlight the various ways in which teachers can incorporate technology into their lesson planning and instructional design. Under *ICT representations* subcategory, the codes encompass various aspects of representation use such as use of non-ICT representations, ICT-infused representations to enhance visualization, motivation, ICT-infused representations to support interactive learning, and ICT-infused representations to facilitate scientific exploration. These subcategories highlight the importance of using visual aids and interactive tools to engage students and enhance their understanding of scientific concepts. Under *teaching method/technique* subcategory, the codes reflect different levels of teacher-centeredness and student-centeredness in the instructional approach. These subcategories highlight the range of teaching methods and techniques used by the teacher, from completely teacher-centered approaches such as lecturing to completely student-centered approaches such as inquiry-based learning.

Finally, the subcategories and codes provided under the category of enactment offer a comprehensive framework for analyzing different aspects of ICT integration during teaching force and motion topics. These subcategories effectively capture the varying levels in ICT guidance, struggling with technical issues, and the infusing ICTs into teaching contexts. Under the subcategory of *ICT guidance*, the different levels of guidance reflect the extent to which ICT tools are utilized to support learning. From insufficient guidance to extensive guidance on scientific thinking and concept building, these subcategories provide insights into the level of support offered through ICT tools during instruction. The subcategory of *struggling with technical issues* addresses the technological challenges that teachers may face when implementing ICT. It includes codes that indicate difficulties encountered, namely unable to continue to topic/class, inadequate technical troubleshooting and backup strategies, seeking spontaneous ICT-based solutions or delaying, and continuing the class calculatedly without interrupting. In the subcategory of *infusing ICTs into teaching contexts*, the codes capture the varying impact of ICT on teaching practices. From believing technology has no contribution to teaching practices to enhancing teaching through convenient ICT use, managing ICTs flexibly and selectively for student learning and instructional management, and skillfully using technology to support student independent learning, these subcategories provide a comprehensive overview of the

integration of ICT into the teaching process.

In reporting, the name of each subdimension and the related code were depicted in brackets to enhance clarity and facilitate easy reference such as '[Understanding student learning needs; using basic ICT tools]’.

4.1.1. Case 1: Asaf

In this section, a detailed analysis of Asaf’s TPACK-P proficiency levels in three educational dimensions was presented. Each was explored to provide insights into the proficiency of integrating technology into pedagogical practices. These dimensions included assessment, planning and designing, and enactment.

4.1.1.1. TPACK-P Proficiency Level for Assessment

Asaf’s proficiency level in assessment dimension was analyzed by combining data from observations of his classes and the semi-structured interview. The TPACK-P framework includes the assessment dimension, which comprises the categories of (1) understanding students’ learning needs and (2) assessment practices. The relevant codes were categorized under these predetermined subcategories, providing a comprehensive analysis of Asaf’s proficiency in assessment.

4.1.1.1.1. Understanding students’ learning needs

In this subdimension, the data was analyzed through classroom observations and semi-structured interview to gain valuable insights into Asaf’s proficiency in using ICT tools to comprehend and address students’ learning needs. This subdimension focuses on a spectrum of teacher’s abilities and methodologies in utilizing ICT to assess their students’ learning requirements, encompassing tasks such as the identification of misconceptions, determination of background knowledge for the topics to teach, and motivation-enhancing strategies. The codes used represent the proficiency levels reflecting how effectively the teacher assess students’ learning needs based on these aspects. The evidence related to these needs were labelled as following codes: unable to use ICT effectively, using basic ICT tools, observing students’ ICT interactions, and using LMS for understanding and structuring self-learning. After providing detailed examples of the teacher’s practices for the available codes, it can be said that Asaf’s

proficiency level in terms of understanding students' learning needs was assessed as simple adoption level.

In order to identify Asaf's TPACK-P proficiency level for assessment in terms of understanding students' learning needs, his answers and actions were analyzed. According to findings, Asaf's proficiency level in terms of understanding students' learning needs seems to be at simple adoption level, particularly in identifying students' background knowledge and possible misconceptions. For example, in one of direct observation of Asaf's classes (Observation of Asaf's 9th class session), it was evident that he started by reminding the students some concepts covered in the previous lesson by saying 'In the previous lesson, we talked about the types of energy and the properties of potential and kinetic energy.' Meanwhile, he tried to locate a specific moment in the animation video on the smart board. After Asaf set that moment on the video, two children appeared on the screen, one with a ball in his hand and the other pulling a box. He asked about the types of energy observed on the screen as well as their subtypes (such as potential energy, gravitational potential energy, or elastic potential energy), and what these energies depend on. Thus, it seems that he was trying to identify any misunderstood or unclear concepts from the previous lesson. In these instances,' Asaf adeptly used animation on the smart board to check students' earlier learning from the previous class [Understanding students' learning needs; using basic ICT tools], which consistent with the rubric's criterion of use of basic ICT tools primarily for understanding students' knowledge.

Similarly, Asaf's simple adoption level of proficiency could be further illustrated in identifying misconceptions. In another class of Asaf (Observation of Asaf's 4th class session), it was observed that he opened a video indicating gravitational potential energy. During the video shown by him, Asaf paused it to draw attention to the difference in weights on the Earth and the Moon. There was a model of the Earth on the screen with an apple on it, and it showed that the apple weighed 6N. On the adjacent model of the Moon, there was also an apple, but it showed that the apple weighed only 1N. The teacher then asked the class why they thought the same apple could be measured at different weights. Many of the students spoke up and explained that it was due to the difference in gravity. After confirming this, the teacher opened the editing tool and typed in 100g. Asaf then asked the class, 'If this apple weighed 100g on Earth

and we took it to the Moon, do you think anything would change?’ After some thought, some students said it would be one-sixth of the weight, while others said it would remain the same. Asaf asked those who said it would decrease to explain their reasoning. Two students replied that it would weigh one-sixth less on the Moon due to the decrease in gravity. He then asked those who said it would remain the same to explain their reasoning. One student explained that the teacher had mentioned grams, so they were discussing mass, which was previously defined as the amount of matter that does not change. Asaf confirmed this and praised the student. Lastly, he reminded the class that one of the most common misconceptions was that mass and weight could be used interchangeably. He emphasized that gravity affected weight, not mass, and urged them to keep this in mind. Upon examining these observations, Asaf demonstrated proficiency in recognizing and addressing common student misconceptions, specifically related to mass and weight distinctions. He utilized a simple animation video to exemplify gravitational potential energy. While his actions showed the ability to identify student misconceptions, his approach to addressing these issues leaned primarily on verbal communication rather than utilizing various ICT tools for deeper engagement and clarification. Consequently, Asaf’s proficiency level reflects his ability to employ ICTs for information presentation and to support his understanding of students’ knowledge [Understanding students’ learning needs; using basic ICT tool].

The interview with the teacher also confirmed these findings from the observations. During the interview, Asaf mentioned that he frequently utilized online learning platforms during class and occasionally using ICT tools to assess students’ prior knowledge:

... It started there [on the learning platform] with questions related to the topic. Sometimes I begin the class by asking questions. From there, I tried to understand the students’ prior knowledge. I can show an event in the videos and try to identify it by asking questions and answering them.

Accordingly, Asaf mentions that he frequently utilizes learning platforms and occasionally incorporates ICT tools to assess his students’ prior knowledge. He initiates lessons with verbal questions to understand the students’ background knowledge and engages them by asking questions related to the topic. In these instances, Asaf primarily uses ICT as to support his understanding of students’

knowledge [Understanding students' learning needs; using basic ICT tools], which is characteristic of the simple adoption level of proficiency according to the defined criterion.

In line with these, Asaf further statements give valuable insights on his proficiency level, particularly identifying misconceptions of students. In response to how he does this, Asaf described these process as follows:

Asaf: ... it usually happens naturally, otherwise I don't do anything specific. I may make an educated guess based on my past experiences or focus on it when it comes up in class. For instance, the concepts of mass and weight are often confused. At the beginning of the class, I point out that this is one of the concepts that students often mix up. I explain, 'Let's learn this concept well first, watch the videos, and do the learning activities before moving on to other concepts and exercises.

Researcher: What tools do you use?

Asaf: I don't have a tool that I use specifically, but I can say that I try to measure from tools that I usually use [in my lessons], such as videos and animations.

Based on Asaf's statements regarding how he identifies misconceptions in his students, his proficiency level suggests a practical approach that aligns with the simple adoption criterion for handling the identification of misconceptions. Asaf acknowledges that recognizing misconceptions often occurs naturally in his teaching, and he does not employ specific strategies for this purpose. He relies on his past experiences and addresses misconceptions as they arise in the classroom. He provides an example of how he deals with misconceptions related to mass and weight by emphasizing the importance of learning this concept before moving on to other topics. While he does not mention using dedicated tools, he occasionally employs videos and animations that are commonly integrated into his teaching. These practices indicate that Asaf primarily utilizes ICT tools in a straightforward manner to address misconceptions when they become evident, which is characteristic of the simple adoption level of proficiency [Understanding students' learning needs; using basic ICT tools. There is also evidence for Asaf's higher proficiency level since he considers student-ICT interactions to understand their learning needs. Asaf's insightful approach extends beyond the mere recognition of students' diverse learning preferences. He actively observes how students interact with ICT tools, realizing their individual learning characteristics. As

he pointed out during the interview:

Sometimes some students are more inclined to learn by listening, some by seeing, and some by interacting. We try to address all of them, both visually and audibly ... I know I am behind my schedule, but I try to complete and finish all the activities both visually and audibly. (...) Sometimes I also resort to game-like activities. For example, when I open the wheel of fortune application (an online tool used to select the student who will do the next activity or action) to have a student come to the smart board, they become very happy and excited in a positive sense. I try to do this because they enjoy it. Apart from that, I sometimes play music. Especially when they are taking notes, I play a song they want through my Bluetooth speaker on Spotify. Sometimes I let the student who gives a nice answer to a difficult question of the day choose the song. They make an effort even to be that person.

Asaf's statements demonstrate his awareness of the diversity in students' learning preferences and styles. He considers the ways in which students prefer to learn, whether through listening, seeing, or interacting. His instructional approach aims to cater to these various learning styles, both visually and audibly. Asaf's mention of utilizing interactive activities and game-like applications, such as the 'Wheel of Fortune', to engage students reflects his observance of students' interactions with ICT tools [Understanding students' learning needs; observing students' ICT interactions]. He notes that students respond positively to such activities and even enjoy them, indicating that he designs his instruction based on students' engagement and preferences. Additionally, his practice of playing music and allowing students to choose songs based on their performance in class further highlights his attentiveness to students' reactions and interactions towards ICT tools. Therefore, Asaf's ability to incorporate various ICT tools while observing and responding to students' learning characteristics suggests an infusive application level of proficiency in this aspect.

In one specific instance during Asaf's teaching (Observation of Asaf's 3rd class session), he effectively employed an ICT tool to determine the order of answering questions, utilizing the 'Wheel of Fortune' digital tool. The utilization of this tool led to a notable increase in student enthusiasm and engagement. As the students enthusiastically participated in the 'Wheel of Fortune' activity, their reactions demonstrated how technology could positively impact student engagement. This exceptional instance stands as a testament to Asaf's practice of recognizing the importance of observing and responding to students' learning characteristics by

analyzing their interactions with ICT resources [Understanding students' learning needs; observing students' ICT interactions].

Overall, Asaf's proficiency level in the subdimension of understanding students' learning needs was assessed as simple adoption level. The evidence suggests that he primarily utilizes basic ICT tools for information presentation and addressing misconceptions, such as clarifying concepts related to mass and weight. While he occasionally incorporates ICT tools to assess students' prior knowledge, Asaf's approach remains aligned with the simple adoption criterion, indicating a practical but straightforward use of technology for understanding students' learning needs. This determination was based on a comprehensive analysis of the available evidence, taking into account the predominant use of basic ICT tools in comparison to more advanced practices, which collectively positions his proficiency at the simple adoption level.

4.1.1.1.2. Assessment practices

In this subdimension, the data was analyzed through classroom observations and semi-structured interview to gain valuable insights into Asaf's proficiency in using ICT tools for formative assessment processes. This subdimension focuses on teacher's diverse ICT-based formative assessment practices for gauging student learning, encompassing various strategies to measure and respond to students' understanding of the content being taught. The codes used represent the proficiency levels reflecting how effectively the teacher assesses students' learning during the teaching based on these aspects. The evidence related to these practices were categorized into the following codes: no use of ICT, using ICT for in-class formative assessment, using ICT for out-of-class formative assessment, and using comprehensive ICT tools enabling product/model design. After providing detailed examples of the teacher's practices for the available codes, it can be said that Asaf's proficiency level in terms of understanding assessment practices was assessed as simple adoption level.

In terms of assessment practices, it was seen that Asaf used various types of formative assessment tools and strategies during his classes. Most of these were comprised of in-class formative assessment techniques such as solving various types of exercise questions from the digital platforms. For example, Figure 9 illustrates a specific instance where Asaf employed in-class formative assessment during a lesson on types

of potential energy and kinetic energy (Observation of Asaf's 11th class session). He presented a set of true-false questions from the online learning platform, Morpa Campus. Students who correctly answered the questions were given the opportunity to respond to additional queries, with a limit of two questions per student. During this activity, one student provided a false response to a question regarding elastic potential energy. In a similar question (a flying bird has both gravitational potential energy and kinetic energy), another student gave the wrong answer again. Then, Asaf asked to the students that 'How many of us agree with our friend?' While seven to eight students agreed with the wrong answer, about half of the class remained silent. Then, he said that 'So it seems we have a deficiency in this topic.' This practice of selecting a student to address questions on the smart board can be regarded as an in-class formative assessment technique [Assessment practices; using ICT for in-class formative assessment]. Surely, it provides the teacher with an opportunity to assess the student's understanding of the topic and identify areas where the student may need additional support or guidance.

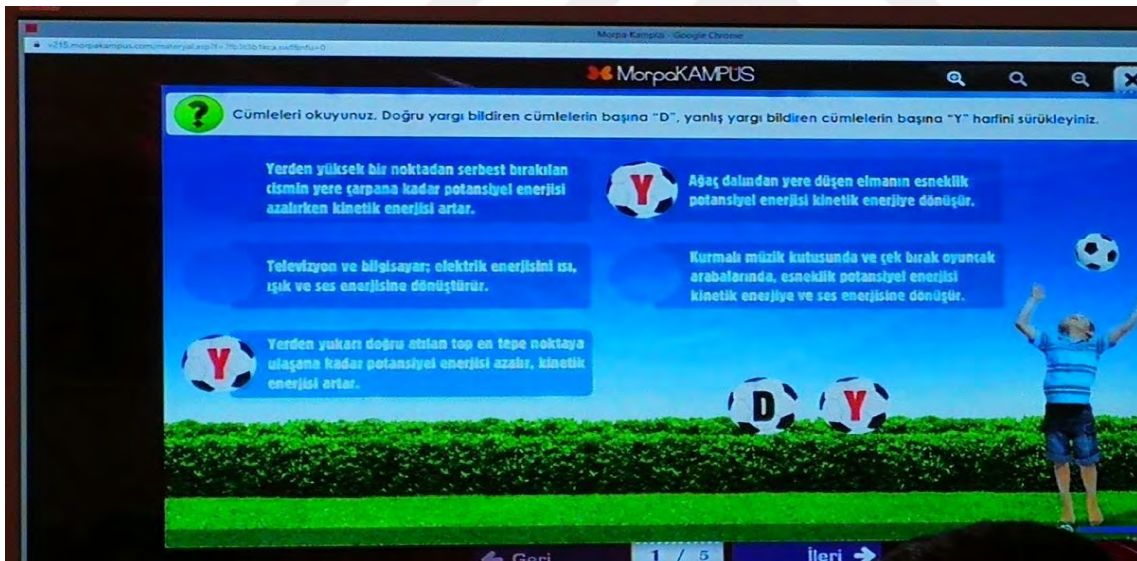


Figure 9. Image of sample true-false exercise questions used by Asaf on the smart board

In addition to the observations made during his classes, Asaf's interview provided further insight into his use of formative assessment tools. He described a range of formative assessment practices as follows:

We are already solving a large number of fill-in-the-blank, matching, sorting, true-false types of questions in the classroom. When we have time, we look at the multiple-choice questions in the z-books together. But since there is little time left for this, we mostly leave solving questions to the course after school hours. Other than that, I sometimes play the game of the Millionaire competition adapted for science.

This highlights his consistent utilization of in-class formative assessments, which aligns with the evidence observed during his lessons. Asaf also mentioned collaborative activities, such as reviewing multiple-choice questions from z-books with students when time permits. However, he acknowledged time constraints, leading them to focus on post-class problem-solving sessions for more extensive assessment. It is worth noting that Asaf's reference to using adapted versions of the 'Millionaire' competition game for science further underscores his proactive approach to varied and engaging formative assessment techniques within his teaching practices. These interview insights corroborate his demonstrated ability to employ ICT tools effectively for in-class formative assessments [Assessment practices; using ICT for in-class formative assessment]. Based on the rubric criteria, Asaf's proficiency aligns with the second level of proficiency (simple adoption) within this subdimension.

Furthermore, the insights gathered from the interview provide additional support for Asaf's demonstrated proficiency level. As mentioned during the interview, Asaf incorporates various formative assessment techniques into his teaching. These include activities such as solving a significant number of fill-in-the-blank, matching, sorting, and true-false questions in the classroom. Moreover, he occasionally engages students in reviewing multiple-choice questions from z-books when time allows. He explains this as "*When we have time, we look at the multiple-choice questions in the z-books together.*" While Asaf is committed to these in-class assessments, his utilization primarily falls within the simple adoption level, as specified in the rubric [Assessment practices; using ICT for in-class formative assessment].

Interview data offer limited evidence to Asaf's higher proficiency level in assessment practices. For instance, Asaf states that he occasionally uses online assessment when utilizing EBA learning management system. As he highlighted, "*I can only give the scores they get on the achievement tests I send via EBA as performance grades,*" suggesting his use of electronic assessment systems for grading [Assessment practices:

using ICT for out-of-class formative assessment]. Another example of his potentially higher proficiency level was observed in his teaching (Observation of Asaf's 13th class session) after completing all subtopics related to air and water resistance in the force and energy unit. Asaf assigned a task to the students involving the design of an online model of a vehicle optimized to minimize air and water resistance. He supplemented this task by displaying a detailed PDF poster outlining the task requirements, available platforms for students, and links to tutorial videos. Since these observations suggest that Asaf incorporates comprehensive ICT tools for engaging students in product/model design activities, it could potentially foster the development of higher-order thinking skills and creativity [Assessment practices; using comprehensive ICT tools enabling product/model design]. Nevertheless, these findings alone are not sufficient to conclude that Asaf's proficiency level exceeds the simple adoption level.

Overall, Asaf's proficiency level consistently remains at simple adoption within the dimensions of assessment practices. This designation reflects his practical yet straightforward use of ICT tools for assessment purposes. His primary focus remains on in-class formative assessments, often involving exercises and questions from digital platforms. While these assessments are diverse and engaging, they generally align with routine teaching practices, characterized by their simplicity and direct application. Although there were some indications of the possibility of higher proficiency levels, the evidence supporting these claims, such as the use of online assessment through LMS or comprehensive ICT tools for product/model design, was relatively scarce compared to the substantial evidence confirming Asaf's proficiency at the simple adoption level. This scarcity of abundant evidence supporting a higher proficiency level emphasizes that Asaf's approach primarily adheres to well-established practices, thus placing him within the simple adoption proficiency level. To sum up, Asaf's proficiency level in both subdimensions of the assessment dimension consistently falls within the simple adoption category as can be seen from Table 7.

Within the subdimension of Understanding students' learning needs, he employs basic ICT tools for information presentation and addressing misconceptions, offering practical but straightforward use of technology to support students' learning. Similarly, in the subdimension of Assessment Practices, Asaf's primary focus revolves around in-class formative assessments, which are diverse and engaging yet remain

rooted in conventional teaching practices, characterized by their simplicity and direct application. While there were some hints of potential higher proficiency levels, the evidence supporting these claims was relatively limited compared to the robust evidence confirming Asaf's simple adoption proficiency. This scarcity of extensive evidence underscores that Asaf's approach predominantly aligns with well-established practices, placing him within the simple adoption proficiency level.

Table 7. The proficiency levels of Asaf in assessment

Name of the Subdimension/Dimension	Proficiency Level
Understanding the students' learning needs	Simple adoption
Assessment practices	Simple adoption
ASSESSMENT	Simple adoption

4.1.1.2. TPACK-P Proficiency Level for Planning and Designing

The TPACK-P proficiency of Asaf in planning and designing were examined under three subcategories. The emergence of these subcategories was determined through a thorough examination and coding of the data. These subcategories, which are namely planning the class, use of ICT representations, and teaching methods, effectively capture different aspects related to planning the class, representations, and teaching methods/techniques in the context of ICT integration in science education.

4.1.1.2.1. Planning the Class

In this subdimension, the data was analyzed through classroom observations and semi-structured interview to gain valuable insights into Asaf's proficiency in planning the class and effectively utilizing ICTs to support teaching and learning, encompassing the preparation and organization of instructional activities, setting educational goals, and aligning them with technology integration. The codes used represent the proficiency levels reflecting how effectively the teacher aligns technology with educational goals and instructional activities based on these aspects. The evidence related to these were labelled as following codes; non-ICT goal setting, using ICT to support teaching, using multiple ICTs to support learning science, and using multiple ICTs to support learning

of and about science. After providing detailed examples of the teacher's practices for the available codes, it can be said that Asaf's proficiency level in terms of planning the class was assessed as simple adoption level.

In terms of planning the class aspect, Asaf's proficiency level can be characterized as simple adoption. The interview data revealed that the Asaf's statements predominantly revolved around the arrangement of ICTs to support the teacher's instruction and assist students in achieving basic learning goals. Asaf acknowledges that in situations where smart boards and digital content are unavailable, he resorts to continuing the lesson using physical textbooks, although acknowledging its lower efficiency compared to ICT-based methods. However, he highlights the advantages of utilizing ICT tools for certain activities, such as conducting experiments with potential risks. To illustrate, Asaf recounts using YouTube to find a visual representation of an experiment involving the output of hydrogen gas, which not only captured the students' attention but also ensured their safety. This demonstrates Asaf's recognition of the value of ICT tools in enhancing teaching and minimizing potential risks, suggesting his proficiency in utilizing ICT to support teaching practices [Planning the class; using ICT to support teaching]. Likewise, Asaf's design goal of ICT-infused class seemed to motivate his students so that more engagement in class could occur. He explained this in the interview as follows:

I realize that they are extra motivated for science lessons because I use them. Also, writing is a chore for students. But because I turned on music while I was writing important parts from the smart board, they said that the teacher should write more. So, they want to see and experience difference. Again, this desire and attention was at its peak in the practice, where we added their names in the wheel of fortune and determined the order to get up on the board.

Accordingly, Asaf acknowledges that utilizing ICT tools in his science lessons has an extra motivational impact on the students. For instance, he mentioned that incorporating music while writing important parts from the smart board led to an increased desire from students for the teacher to write more, indicating heightened engagement. These instances highlight Asaf's ability to leverage ICT tools to enhance motivation and engagement in his teaching practices, suggesting a simple adoption level of proficiency in planning the class aspect [Planning the class; using ICT to support teaching]. On the other hand, it is important to note that no evidence was found

to support a higher level of proficiency. While Although Asaf expressed that he was able to identify and clarify students' misconceptions during teaching, his planning skills did not involve strategically selecting different ICT tools such as interactive simulations, multimedia resources, or online platforms, to reinforce students' understanding of concepts and address their misconceptions based on his statements, which would be indicative of a higher level of proficiency (e.g., using multiple ICTs to support learning science). As a result, Asaf's TPACK proficiency in terms of planning the class remains at simple adoption level.

Overall, in the subdimension of planning the class, Asaf's TPACK proficiency can be characterized as a simple adoption level. He effectively utilizes ICT tools to support his teaching practices by incorporating them into his lessons, which has a positive impact on student motivation and engagement. Asaf's use of ICT tools, such as smart boards and multimedia resources, demonstrates his ability to align technology with educational goals and instructional activities. However, his proficiency remains at the simple adoption level because he primarily focuses on basic learning goals and lacks evidence of strategically selecting various ICT tools to address students' misconceptions and enhance their understanding of science concepts.

4.1.1.2.2. ICT Representations

In this subdimension, the data was analyzed through classroom observations and semi-structured interview to gain valuable insights into Asaf's proficiency in utilizing ICT representation during teaching. The codes used represent the proficiency levels reflecting how effectively the teacher integrates ICT representations into his instructional practices. The evidence related to these were labelled as following codes: non-ICT representations, visualization and motivation enhancement, interactive learning support, and scientific exploration support. After providing detailed examples of the teacher's practices for the available codes, it can be said that Asaf's proficiency level in terms of ICT representation was assessed as simple adoption level.

Regarding ICT representations, Asaf used different kinds of representations mainly in order to support visualization and motivation purposes. The data provided particularly strong evidence of this, especially through classroom observations. For example, Asaf opened a simple experiment related to the compression of a spring when mass is placed

on it on the smart board (Observation of Asaf's 9th class session). This specific e-experiment simulation showcased his effective use of ICT-infused representations, which fostered a visually engaging and motivating learning environment. By incorporating interactive simulations and visual aids, Asaf effectively leveraged technology to encourage students to explore and understand scientific concepts in a more interactive and visually appealing manner [ICT representations; visualization and motivation enhancement]. However, while his proficiency aligns with simple adoption level, the data does not provide clear evidence to suggest that students were actively engaged in the experimentation process with ICT-infused representations, which is a key characteristic of infusive application (Interactive learning support).

Furthermore, a similar instance was observed in another class of Asaf where he intended to begin gravitational force by asking questions related to weight in different heavenly objects (Observation of Asaf's 3rd class session). During the lesson, Asaf skillfully incorporated an introductory video to introduce the subject and engage students by enhancing their motivation to delve deeper into the topic. By strategically pausing the video at key moments and posing thought-provoking questions, Asaf actively encouraged student participation, fostered critical thinking, and facilitated a more profound understanding of gravitational force [ICT representations; visualization and motivation enhancement]. These efforts, where students could find opportunities to articulate their comprehension and engage in valuable question-and-answer interactions, effectively exemplify Asaf's skill in enhancing students' motivation and understanding of gravitational force through the use of ICTs.

Another example illustrating Asaf's proficiency level in terms of ICT representation at the simple adoption level was his skillful utilization of smart board editing tools.''' When teaching the concept of weight measured on Earth and the Moon (Observation of Asaf's 4th class session), he demonstrated the practical use of the editing tool on the smart board. Asaf employed this tool to construct a table that depicted an object's mass on Earth as illustrated in Figure 10. This table enabled Asaf to pose thought-provoking questions to the students about the changes in mass and weight when the same object is measured as 100g on Earth and the Moon. By utilizing a variety of colored pencil tools, Asaf conducted the essential calculations and documented the outcomes within the table's empty sections. Based on these findings, it is evident that this visual ICT

representation effectively organized and presented information in a clear and structured manner, enhancing students' comprehension, and facilitating effective communication of concepts [ICT representations; visualization and motivation enhancement].

If an object measures as 100 g in the Earth:	
A) How much does it weigh in the Earth? $(100\text{g} / 1000) \times 10 = 1 \text{ N}$	B) How much does it weigh on the Moon? $(100\text{g} / 1000) \times (10 / 6) = 0,17 \text{ N}$
C) What is its mass in the Earth? 100 g	D) How much is its mass on the Moon? 100 g

Figure 10. Representation of the table that Asaf drew on the smart board screen regarding the weight-mass comparison

Similarly, Asaf opened a new animation titled ‘What does the size of physical work depend on?’ when teaching physical work topic in another class (Observation of Asaf’s 8th class session). The animation featured two children exerting force on different-sized chests. One child exhibited height and strength, while the other possessed a shorter and thinner physique. After the animations of the children’s actions finished, Asaf paused it to clearly explain the direct link between the amount of work and the force used. This specific moment showed Asaf’s skill in using ICT-enhanced visuals to improve understanding and increase enthusiasm in the class. Moreover, observations revealed that Asaf often used a range of ICT tools, like animations, videos, and simulations, to present new ideas and reinforce what the students learned. These tools seemed to be key in attracting the students’ attention visually and may have led to a deeper understanding of the subjects [ICT representations; visualization and motivation enhancement]. It was also noted that Asaf sometimes livened up the classroom by playing music from his smartphone through a Bluetooth speaker while students were writing notes. This further highlighted his ability to use technology and multimedia tools to create a lively and motivating learning atmosphere [ICT representations: visualization and motivation enhancement]. Overall, the combination of the observed animation usage, the utilization of various ICT tools, and the incorporation of music demonstrated Asaf’s proficiency in effectively employing ICT-infused representations to enhance visualization and motivation among his students,

concluding a simple adoption level.

Furthermore, Asaf's self-report during the interview suggests that his main aim of using representations was to enhance visualization and motivation. When asked about the effect of ICT on better comprehension of science concepts, Asaf stated,

It appeals to many senses as it is both visual and auditory. This helps them grasp the concepts better. Because they are more interested when we use technology, I observe that they follow the lesson carefully and with pleasure.

These statements emphasized that incorporating visual and auditory elements through technology appeals to students' multiple senses, aiding in their understanding and comprehension of scientific concepts [ICT representations; visualization and motivation enhancement]. Moreover, the mention of increased student interest suggests that the use of technology and representations contributes to a more engaging learning environment.

The data suggested that Asaf's aim in using ICT representations was primarily to enhance visualization and motivation. Although there were several pieces of evidence indicating that Asaf's use of representations also extended to supporting interactive learning through ICT tools, there was no explicit evidence of students actively engaging with ICT-infused representations or instruments. Along with his responses in the interview, it is apparent that Asaf often paid attention to give opportunities for his students to interact with the teaching activities and ICT tools. He described these efforts as:

I care very much about putting the students on the smart board one by one. I encourage them to do this. Because when they do, their self-confidence increases, and they see what they can do. Sometimes they get stuck, and they can't do it, I help them from there, I make him succeed again. At least they see where their mistake is and so do I.

In line with these, Asaf's primary aim in using ICT representations was to enhance visualization and motivation. However, while there were indications of the potential for interactive learning support, these aspects were not explicitly detailed in the provided data. Asaf's descriptions during the interview emphasized the use of ICT representations to enhance students' engagement, understanding, and motivation [ICT representations; visualization and motivation enhancement]. For example, he

mentioned the positive impact of technology on students' interest and attentiveness during lessons. However, the interview did not delve into specific practices related to interactive learning support, such as students actively engaging with ICT-infused representations. Therefore, Asaf's proficiency level in this context aligns more closely with simple adoption level.

In some instances, it appeared that Asaf demonstrated a higher level of proficiency in utilizing representations to support his teaching, thereby fostering interactions between students and ICT tools. In one instance (Observation of Asaf's 10th class session), an interactive experiment took place where Asaf often paused the animation to explain the relationship between elastic potential energy and displacement. The animation involved an iron ball that compressed a spring fixed to the wall. One student stood up and tapped the smart board screen, squeezing and releasing the marble, while he instructed the students to make careful observations of the changes. Afterwards, he guided the student on the smart board to use the pen tool and record the findings in an available space on the screen. The student noted the following observations: 'It moves 8 m when compressed by 4 cm' and 'When compressed by 5 cm, it moves 10 m.' Additionally, another experiment was conducted on the smart board involving a flexible rubber cover and a ping pong ball. A student performed the experiment, and similar to the previous one, Asaf directed the student to use the pen tool to record the measurements in an available area. The student wrote the following findings: 'When dropped from 3 meters, it goes down 3 units' and 'When released from 1 meter, it goes down 1 unit.' These classroom observations highlight the interactive and hands-on nature of Asaf's teaching approach, where representations are effectively utilized to enhance student engagement, understanding, and visualization of scientific concepts. It is evident that Asaf's use of ICT-infused representations to support interactive learning aligns with his proficiency in planning and designing instructional activities. With the inclusion of hands-on experiments and use of the smart board's capabilities, Asaf shows his skill in blending technology into his lessons to boost student involvement and better understanding. These insights highlight his expertise in picking and creating fitting visuals that enable interactive learning, allowing students to take part actively in discovering and dissecting scientific ideas. Asaf's purposeful use of the pen tool and the students' engagement in noting their discoveries on the smart

board further display his skill in setting up and creating tasks that encourage student teamwork, thoughtful analysis, and self-reflection. Overall, Asaf's utilization of ICT-infused representations to support interactive learning demonstrates his competence in leveraging technology to create meaningful and engaging learning experiences for his students [ICT representations; interactive learning support].

Along with these, his statements during interview such as *"I care very much about putting the students on the smart board one by one. I encourage them to do this. Because when they do, their self-confidence increases, and they see what they can do."* corroborated his deliberate intention to actively involve students to engage with ICT tools. By facilitating their active participation, he aims to enhance their engagement in the classroom. Asaf's dedication to technology and student involvement shows his commitment to creating a dynamic learning environment where students take an active role in learning experiences and conceptualization of scientific concepts [ICT representations; interactive learning support].

Overall, Asaf's proficiency in utilizing ICT representations falls within the simple adoption level, primarily focusing on enhancing visualization and motivation. While there are indications of potential for interactive learning support, this aspect was not explicitly detailed in the provided data. Asaf's commitment to actively involving students and creating a dynamic learning environment is evident, aligning more closely with the interactive learning support level in the context of ICT representations. However, due to the lack of explicit evidence of such practices in the data, the determination of a simple adoption level is more strongly supported.

4.1.1.2.3. Teaching Methods/Techniques

In this subdimension, the data was analyzed through classroom observations and semi-structured interview to gain valuable insights into Asaf's proficiency in instructional strategies with varying degrees of student-centeredness when using ICTs. This subdimension assesses to teacher's preferences regarding the centeredness of teaching. The evidence related to these approaches were labelled with the following codes: completely teacher-centered, mainly teacher-centered, mainly student-centered, and completely student-centered. After providing detailed examples of the teacher's practices for the available codes, it can be said that Asaf's proficiency level in terms

of teaching methods/techniques was assessed as simple adoption level.

Concerning the teaching methods/techniques, the teacher's tendency to use teaching methods or techniques from completely teacher-centered strategy to completely student-centered strategy was examined through interview and classroom observations. Accordingly, a piece of evidence showed that Asaf's teaching centeredness seems to be distant from using student-centered teaching methods. While he encourages students to participate actively in the class, he mentioned that "*it can be counted as making students watch videos and animations*", indicating that the role of students is passively watch the screen and listen the explanations if there is also voiceover in these visuals. This suggests that Asaf's utilization of ICT tools aligns more with a teacher-led teaching approach, resulting in his basic proficiency level [Teaching methods/techniques; completely teacher-centered].

Furthermore, there was evidence in Asaf's data indicating that his teaching methods leaned less toward being completely teacher-centered and instead exhibited characteristics of mainly teacher-centered teaching methods with some degree of student interaction. An example of this was observed when a different graphics question related to kinetic energy was presented (Observation of Asaf's 11th class session). Instead of exclusively adopting a completely teacher-centered, one-way communication approach, Asaf asked a student who stood up to answer to sit down, stating, 'this question is a little different, so it would be better if we solve it together.' He then zoomed in on the question for better visibility and proceeded to explain how to consider such questions. While Asaf provided guidance during the problem-solving process, he actively encouraged students to participate and interact with the content. For instance, after stating, 'If it is given that there is 8E energy at point A, what type of energy is this?' Asaf prompted the students to respond, and they correctly identified it as potential energy. In this way, students were actively involved in the problem-solving process, which highlights the mainly teacher-centered nature of the teaching methods employed in the classroom with some student interaction and collaborative problem-solving [Teaching methods/techniques; mainly teacher-centered].

Additionally, there is another piece of evidence revealing Asaf's teaching approach tended to more student-centered. For instance, his statement during the interview such

as *“From time to time, when I make students watch something, I often stop and ask questions or explanations. We carry out the process by exchanging ideas and information.”* suggests that while there may be occasional instances of student-centeredness in his approach, his overall proficiency and inclination are more aligned with a predominantly teacher-centered methodology [Teaching methods/techniques; mainly teacher-centered].

However, one notable exception to this pattern was observed when Asaf assigned a design task to his students, asking them to create an online drawing of a vehicle optimized for air, water, and surface resistance (Observation of Asaf’s 13th class session). In this instance, Asaf took a different approach by providing an informational poster that outlined the task’s content and description. As a result, the students were able to independently engage in the process of model building using scientific principles [Teaching methods/techniques; completely student-centered]. This particular observation serves as compelling evidence of Asaf’s utilization of a student-centered teaching method, reaching the highest proficiency level, which was labelled as completely student-centered.

Overall, Asaf’s teaching methods and techniques tend to lean more towards mainly teacher-centered strategies, with limited instances of more student-centered approaches. His general approach is primarily teacher-centered, where students often engage passively with instructional materials. However, there was one notable exception when Asaf assigned a design task to his where he employed a completely student-centered teaching method, reaching the highest proficiency level in this subdimension. Nonetheless, his overall inclination aligns more with teacher-centered methods, emphasizing the importance of enhancing student motivation and understanding of the content while allowing for some interaction with students, though with the teacher still leading. Therefore, his proficiency level in teaching methods and techniques was assessed as simple adoption, given his overall preference for mainly teacher-centered approach. This assessment was supported by the data at hand, which reflects his typical teaching approach along with occasional utilization of more student-centered methods.

Table 8. The proficiency levels of Asaf in planning and designing

Name of the Subdimension/Dimension	Proficiency Level
Planning the class	Simple adoption
ICT Representations	Simple adoption
Teaching method/technique	Simple adoption
PLANNING and DESIGNING	Simple adoption

To sum up, it is evident that Asaf's proficiency level in the planning and designing dimension consistently falls within the simple adoption category as seen in Table 8. His primary focus lies in the utilization of representations to enhance visualization and motivation within the class. However, his approach predominantly leans toward teacher-centered teaching methods rather than extensively supporting interactive learning. As such, Asaf's overall proficiency in planning and designing the class reflects a preference for conventional strategies and simple technology integration, placing him firmly within the simple adoption proficiency level.

4.1.1.3. TPACK-P Proficiency Level for Enactment

In this section, the observation data and interview records were analyzed to explore the teacher's TPACK-P proficiency in terms of enactment, focusing on three subcategories: ICT guidance, struggling with technical issues, and infusing ICTs into teaching contexts. The data provided valuable insights into Asaf's competence in effectively integrating technology during instructional delivery.

4.1.1.3.1. ICT guidance

In this subdimension, the data was analyzed through classroom observations and semi-structured interview to gain valuable insights into Asaf's proficiency in guiding in utilizing ICT tools for science instruction. This subdimension focuses on the quality of ICT guidance provided by the teacher. The evidence related to this guidance were labelled with the following codes: insufficient guidance, verbal and visual instruction, learning facilitation with practice, and extensive scientific thinking and concept

building. After providing detailed examples of the teacher's practices for the available codes, it can be said that Asaf's proficiency level in terms of ICT guidance was assessed as simple adoption level.

Concerning the ICT guidance, the interview and observation data reveal Asaf's guidance approach to using ICT tools as a means to aid students when they encounter difficulties understanding complex concepts or terms during the class. In this manner, Asaf expresses himself that he sometimes tries to use ICT tools when his students have difficulties in understanding concepts or terms during the class. For instance, he stated this as *"For example, if there is a word called ceramics, it can be difficult to explain it to students sometimes. Then, I help them understand by writing ceramics in the search engine and showing its image."* Asaf mentions using a search engine to look up the word 'ceramics' and showing its image to help students understand. This practice indicates his strategy of utilizing both verbal explanations and visual aids, such as images, to assist students in grasping complex concepts [ICT guidance; verbal and visual instruction]. Additionally, by demonstrating how to perform online search, Asaf indirectly guides his students on effectively using ICT tools for their own learning purposes. Since this guidance lacks a clear structure or organization in terms of logical coherence, it might require further improvement to enhance comprehension or learning facilitation. Therefore, this example implies that Asaf's proficiency level is at simple adoption.

In similar, there were further instances to this level of ICT guidance in the classroom observations. In one of Asaf's classes (Observation of Asaf's 3rd class session), it was observed that after solving various related practice questions about force and the amount of extension in the spring, he explains that he has a tool for students to conduct experiments and observations on such topics. He showed the students a way to find resources about the lesson. He demonstrated how to navigate to Google and type the keyword 'phet', then accessed the site and opened the simulations related to their courses. Next, he initiated the 'Masses and Springs' simulation by stating, 'Let's look at a simulation related to our lesson today.' Asaf took charge of starting and overseeing this initial simulation. He explained the gravity-weight relationship to his students by manipulating the variables. Based on this observation, Asaf's ICT guiding approach was primarily focused on providing visual and verbal support to the students. He

demonstrated how to access online resources and open simulations related to the lesson. However, it is worth noting that the guidance provided was mainly limited to explaining and showcasing the use of technology, with less emphasis on actively involving the students in hands-on practice [ICT guidance; verbal and visual instruction]. While his visual and verbal support was helpful in introducing the topic and demonstrating concepts, there appeared to be limited opportunities for the students to engage with the technology themselves and apply their learning in a more interactive manner.

Similarly, Asaf employed a similar approach when assigning a drawing task related to designing a vehicle optimized for air and water resistance (Observation of Asaf's 13th class session). Despite introducing Tinkerpad and 3D Modeling applications on the smart board, he provided only a basic description of how students could use these tools during the class [ICT guidance; verbal and visual instruction]. Consequently, his guidance appears to be less effective in facilitating active student involvement and practical application of ICT tools.

On the other hand, there were some pieces of evidence that suggest Asaf's guidance can be considered in a more sophisticated manner. That is, he sometimes helped his students when they stuck with ICT tools on the smart board. For instance, it was observed that when the student made an operational error while calculating with the pen tool on the smart board screen (Observation of Asaf's 5th class session), Asaf noticed this and asked her to check whether she had performed the operation correctly. Upon realizing her mistake and informing the teacher, she crossed out the marked area. Asaf then guided her in locating the eraser tool on the screen and allowed her to delete the incorrectly written line. Additionally, Asaf instructed her to write the corrected value in a different color. Subsequently, the student found it and wrote the weight as 90N in red color. According to this observation, it is evident to say Asaf actively engages with the student's error, prompts her to self-reflect, and provides assistance in finding and using the appropriate tool to correct the mistake. By encouraging the student to actively participate in the process and practice using the technology, he promotes a more hands-on learning experience. This demonstrates Asaf's proficiency in guiding students to learn and apply their knowledge through interactive engagement with ICT tools by actively involving them in the process [ICT guidance; learning

facilitation with practice]. Similarly, Asaf consistently employed this type of guidance throughout his classes, actively seeking student input and participation. For instance, when the sound of an animation could not be heard, he proactively included a student by asking them how to increase the volume on the smart board. Therefore, his ability to facilitate student learning through interactive guidance and student inclusion remains evident.

Overall, within the ICT guidance subdimension, Asaf's proficiency level is assessed at simple adoption. His approach primarily centers on providing visual and verbal support to students to help them understand complex concepts or terms using ICT tools. Although his guidance offers valuable assistance, it could benefit from a more structured and logically coherent approach to enhance comprehension. While there were instances where he facilitated interactive learning by engaging students in the ICT tools, these were less frequent compared to the primarily instructional approach observed in his teaching practices. The determination of his proficiency at the simple adoption level was supported by the data available, which showcases a predominance of instructional guidance over interactive approaches.

4.1.1.3.2. Struggling with technical issues

In this subdimension, the data was analyzed through classroom observations and semi-structured interview to gain valuable insights into Asaf's proficiency handling technical issues during his teaching. The evidence from the interview data related to this guidance were labelled with the following codes: unable to proceed with the topic/class, inadequate technical troubleshooting and backup strategies, seeking spontaneous ICT-based solutions or delaying, and continuing the class calculatedly without interrupting. After providing detailed examples of the teacher's practices for the available codes, it can be said that Asaf's proficiency level in terms of struggling with technical issues was assessed as infusive application level.

In terms of struggling with technical issues, Asaf mentioned his experiences in earlier classes during the interview. He provided an example, stating, *"If we do not have a smart board or access to digital content, or if there is a power outage, we continue the lesson using the physical book."* At first glance, it appears that Asaf has a backup plan in case there are issues with ICT tools, whether related to hardware or software.

However, he did not specify whether he follows a predetermined plan for non-ICT teaching or if he improvises in such situations [Struggling with technical issues; inadequate technical troubleshooting and backup strategies]. Asaf's efforts in handling technical issues here seem to be more aligned with simple adoption level (Inadequate technical troubleshooting and backup strategies), where the teacher may lack backup plans and sometimes struggles to resolve technical problems, potentially resulting in a reversion to traditional teaching methods. This conclusion is further supported by his statements about planning his science class without written or organized lesson plans, such as *"We no longer prepare daily lesson plans"* and *"... I attempt to utilize all available ICT tools based on the course's progression"*, it can be inferred that he tends to improvise the remainder of the class if technical problems prevent the use of ICT tools. While Asaf mentions having a backup plan in case of technical issues with ICT tools, the lack of clarity regarding a predetermined plan for non-ICT teaching suggests a potential inadequacy in his technical troubleshooting and backup strategies.

Conversely, Asaf appears to be more proficient in solving certain technical issues during class. His experiences contribute to the swift resolution of these problems. For example, his statements such as *"If the internet [on the smart board] is disconnected, I can connect my phone's internet to the smart board"* and *"Sometimes the touch screens of smart boards may malfunction. We usually wipe it with a solution cloth, then it can be convenient to use again"* indicate that he can effectively address such issues during class based on his experiences and ICT skills [Struggling with technical issues; seeking spontaneous ICT-based solutions or delaying]. Similar evidence was obtained both in interview and classroom observation. Asaf stated that *"For example, my Tinkercad membership was linked to my Facebook account. So, I have to create a new account with my e-mail. It took some time but we solved the problem"* during the interview. It was observed that he came across this problem when he introduced how to use Tinkercad application to his students. After figuring out this malfunction, he quickly signed up with a new account. Afterwards, he could introduce and guide the use of Tinkercad application. Thus, as Asaf demonstrates the ability to address various technical issues and adapt his use of ICT tools, it suggests a higher level of proficiency [Struggling with technical issues; seeking spontaneous ICT-based solutions or delaying]. However, the absence of strong backup plans for significant issues indicates

that his proficiency level may still have room for improvement.

Overall, Asaf's proficiency level in handling technical issues during his teaching falls within the simple adoption level. While he displays some proficiency in addressing technical problems during class, his overall approach lacks clear backup plans, and he occasionally resorts to traditional teaching methods when encountering technical challenges. The absence of well-defined backup strategies for significant issues suggests room for improvement in his technical troubleshooting skills. Although he shows adaptability and the ability to seek spontaneous ICT-based solutions, his proficiency level primarily aligns with simple adoption due to the need for more structured backup plans and strategies for non-ICT teaching scenarios. This assessment was rooted in the data available, demonstrating a preference for practical but basic approaches when dealing with technical challenges during instruction.

4.1.1.3.3. Infusing ICTs into teaching contexts

In this subdimension, the data was analyzed through classroom observations and semi-structured interview to gain valuable insights into Asaf's proficiency strategically integrating ICT tools into his teaching practices to enhance the overall learning environment. This subdimension focuses on a range of approaches and strategies employed by the teacher to seamlessly incorporate ICTs into instructional contexts, ultimately contributing to an enriched teaching and learning experience. The codes used reflect Asaf's proficiency levels in terms of infusing ICTs into teaching contexts, which highlight the effectiveness and depth of his integration. These proficiency levels encompass the belief that ICTs offer no contribution to teaching practices, the use of basic and convenient ICT tools for instructional enhancement, flexible and selective management of ICTs for instructional purposes, and skillful use of technology to foster student independence. After providing detailed examples of the teacher's practices for the available codes, it can be said that Asaf's proficiency level in terms of infusing ICTs into teaching contexts was assessed as infusive application level.

In evaluating Asaf's proficiency in infusing ICTs into teaching contexts, it is important to consider his beliefs and practices regarding the contribution of technology to teaching practices. It should be noted that the results presented here are derived exclusively from the interview data, as there was absence evidence in the observation

data. Asaf expresses that ICT tools play a valuable role in supporting his classroom management, as evidenced by his statements:

If the student follows the lesson more carefully and learns the subject better, which I always try to do with ICT tools, I think it is an effective teaching. If we do not count minor problems, I do not think that it has a negative effect on my classroom management. I can say that ICT tools make more positive contributions to my classroom management as they enable everyone to participate in the lesson rather than students who are dealing with other things in the back row. There is even this: I said that the student enjoys listening to music while taking notes. Honestly, I'm enjoying it too. I feel rested.

Accordingly, Asaf emphasizes the positive impact of ICT tools on teaching effectiveness, noting that using them helps students engage more attentively and achieve better learning outcomes [Infusing ICT into teaching contexts; enhancing teaching through basic and convenient ICT integration]. This proficiency level indicates that Asaf adeptly utilizes easily accessible ICT tools to enhance classroom instruction and effectively engage students. His belief in the positive influence of technology on teaching practices aligns with this code, demonstrating his capacity to seamlessly integrate ICT tools into his teaching for improved student learning experiences.

Similarly, his emphasis on the criteria for a successful class relates to the enjoyment and attentiveness of his students, as indicated by his statement. *“For example, there was a content I prepared about the friction force. There were also funny visuals in it, it's fun along with the music ... They enjoyed it very much and followed the lesson with great attention.”* Accordingly, Asaf's perspective implies that his choice of convenient ICT tools is primarily aimed at enhancing teaching through making it more interesting and better supported for engaging [Infusing ICT into teaching contexts; enhancing teaching through basic and convenient ICT integration]. This aligns with the lower level of proficiency in infusing ICTs into teaching contexts, where the focus is on using ICTs for convenience and entertainment rather than for comprehensive integration and skillful utilization to support student learning and independent exploration.

Furthermore, there is also evidence indicating Asaf's proficiency in terms of infusing ICTs into teaching contexts seems to be higher. Asaf acknowledges that minor issues related to ICT tools do not significantly affect his classroom management, indicating

his ability to address and overcome such challenges. Asaf further highlights the inclusive nature of ICT tools, allowing all students to actively participate in the lesson and avoiding distractions for those seated at the back. His mention of students enjoying listening to music while taking notes showcases his ability to incorporate diverse strategies using ICT tools, which he finds personally enjoyable and refreshing [Infusing ICT into teaching contexts; flexible and selective management of ICTs for student learning and instructional management]. These statements demonstrate that his ability to address minor issues and create an inclusive, engaging classroom environment through diverse ICT strategies underscores his competence in infusing ICTs into teaching contexts effectively.

In similar, when asked about the role of ICT tools in executing and supervising his teaching process during the interview, Asaf stated that “*ICT tools make it easy for me to follow this [whole] process, whether it’s the activities [by] students are doing, [or] the results of the homework and tests I’ve sent from EBA.*” Accordingly, Asaf acknowledges their convenience in monitoring student activities and accessing homework and test results through platforms like EBA. Referring to his previous statement about his students enjoying the lesson with ICT tools, this example serves as evidence of a higher proficiency in infusing ICT into the teaching context, some of his statements point to a lower level of proficiency. For instance, when asked about how ICT tools impact the performance of his classes, he responded as follows:

It affects positively. It makes more fun. Children listen more carefully and participate because they have fun. ... It also helps me reach my goals in less time. Moreover, I think it is more effective for them to learn.

These statements suggest that his students’ enjoyment and the substantial integration of ICT tools contribute to an effective class since they foster a more interactive and engaging learning environment [Infusing ICT into teaching contexts; flexible and selective management of ICTs for student learning and instructional management]. This aligns with the proficiency code reflecting flexible and selective management of ICTs for student learning and instructional management.

Overall, Asaf’s proficiency level was assessed as infusive application, indicating his ability to enhance classroom instruction and engage students effectively through basic and convenient ICT integration. While there is some evidence suggesting a simpler

adoption level due to a focus on convenience and entertainment, the prevailing indications of higher proficiency stem from his capacity to address minor issues, create an inclusive and engaging classroom environment, and use ICT tools for flexible and selective management, ultimately fostering a more interactive and effective learning environment. The chosen proficiency level highlights his adeptness in effectively integrating ICT tools for teaching purposes.

Table 9. The proficiency levels of Asaf in enactment

Name of the Subdimension/Dimension	Proficiency Level
ICT guidance	Simple adoption
Struggling with technical issues	Simple adoption
Infusing ICTs into teaching contexts	Infusive application
ENACTMENT	Simple adoption

To sum up, Asaf's TPACK-P proficiency level appears to be at simple adoption in terms of enactment. As can be seen from Table 9, the proficiency level was assessed as simple adoption within the ICT guidance subdimension. Asaf demonstrates a primarily instructional approach with a focus on providing visual and verbal support to students. While his guidance is beneficial, there is room for improvement in terms of creating a more structured and logically coherent approach to enhance comprehension. In the subdimension of struggling with technical issues, Asaf exhibits a simple adoption level of proficiency. While he shows some skill in addressing technical problems during class, his approach lacks well-defined backup plans, occasionally resorting to traditional teaching methods when faced with technical challenges. This suggests a need for more structured troubleshooting strategies. However, in the subdimension of infusing ICTs into teaching contexts, Asaf's proficiency level appears to be infusive application. He acknowledges the positive impact of ICT tools on teaching effectiveness, emphasizing their role in enhancing classroom management and engaging students. Some evidence also points to simple adoption levels in his approach, highlighting a focus on convenience and entertainment over comprehensive integration of ICTs for teaching. Therefore, it is reasonable to

conclude that Asaf's proficiency level in infusing ICTs into teaching contexts is more likely at simple adoption level.

4.1.2. Case 2: Bora

In this section, a detailed analysis of Bora's TPACK-P proficiency levels in three educational dimensions was presented. Each dimension was explored to provide insights into the proficiency of integrating technology into pedagogical practices. These dimensions included assessment, planning and designing, and enactment.

4.1.2.1. TPACK-P Proficiency Level for Assessment

Bora's proficiency level in assessment dimension was analyzed by combining data from observations of his classes and the semi-structured interview. Within the TPACK-P framework, the assessment dimension encompasses understanding students' learning needs and assessment practices. These predetermined subcategories received the relevant codes which allowed for a thorough analysis of Bora's proficiency in assessment.

4.1.2.1.1. Understanding students' learning needs

In this subdimension, the data was analyzed through classroom observations and semi-structured interview to gain valuable insights into Bora's proficiency in using ICT tools to comprehend and address students' learning needs. This subdimension focuses on a spectrum of teacher's abilities and methodologies in utilizing ICT to assess their students' learning requirements, encompassing tasks such as the identification of misconceptions, determination of background knowledge for the topics to teach, and motivation-enhancing strategies. The codes used represent the proficiency levels reflecting how effectively the teacher assess students' learning needs based on these aspects. The evidence related to these needs were labelled as following codes: unable to use ICT effectively, using basic ICT tools, observing students' ICT interactions, and using LMS for understanding and structuring self-learning. After providing detailed examples of the teacher's practices for the available codes, it can be said that Bora's proficiency level in terms of understanding students' learning needs was assessed as simple adoption level.

A detailed analysis was carried out on the transcriptions of classroom observations and the interview to understand Bora's TPACK-P skill level for assessment in relation to understanding students' learning needs. For example, the interview data showed Bora's level of proficiency in this subdimension when how he explained his method for evaluating his students' learning needs. He noted that he starts by figuring out how ready his students are at the beginning of a unit. He explains this as follows:

In the beginning of the unit, I measure the students' readiness level. When assessing their readiness level, I ask them some questions. While asking these questions, I can show various visuals, display images on the board, or even read a story, and then I measure the students' readiness level by asking questions based on these materials.

Bora states that he is able to determine his students' background knowledge by asking questions and using different ICT-based visuals like pictures or stories to get the students involved and check their readiness. Bora also highlighted the need to create curiosity in his students by asking questions that make them think about the topic that's coming up. He noticed that when students start asking questions, they become more interested in the lesson. To further enhance their understanding, Bora employs a range of visuals and animations to delve deeper into the subject matter and effectively teach the lessons. These pieces of evidence imply his skills to understand students' learning needs in terms of determination of earlier learning by using basic ICT tools [Understanding students' learning needs; using basic ICT tools] without paying attention to any student-ICT interactions, suggesting simple adoption level of proficiency.

The interview data also sheds light on Bora's proficiency in utilizing ICT tools for understanding students' learning styles. He explains that he can identify what kind of ICT tools or content may enhance their attention and ultimately learning. According to him, these tools involve audial and visual aids, and the cultivation of student curiosity. His approach demonstrates an awareness of the importance of understanding his students' learning needs and creating an engaging learning environment. Similarly, his further statements supported these statements since the use of ICT tools leverages learning the topics as follows:

They understand the lessons we teach better with the possibilities of technology. Seeing and hearing the visual-based examples there rather than my speaking

contributes to their understanding and learning.

In line with this, Bora's acknowledgment of the benefits of technology in improving students' comprehension aligns with his approach of incorporating visuals and interactive elements into his lessons. He recognizes that students are highly engaged with screens due to their extensive exposure to television and smartphone usage. Bora emphasizes, *"It becomes interesting [to them]. Because students watch TV and play on the phone all their lives. So, they are familiar with screens. When we open something on the screen, it attracts them."* This shows Bora's understanding of his students' learning needs and how he uses their comfort with technology to make a more interesting learning atmosphere [Understanding students' learning needs; using basic ICT tools]. Therefore, Bora's proficiency level based on these pieces of evidence seems falls within simple adoption level as he effectively employs basic ICT tools, such as visual aids and interactive elements, only to enhance students' attention, comprehension, and learning, demonstrating his ability to recognize and cater to his students' learning needs through technology.

Bora not only engages students but also effectively employs ICT tools to help them overcome learning challenges. During a class session (Observation of Bora's 7th class session), Bora brought up the subject of energy transformations and aimed to gauge his students' grasp of energy conservation. He threw a question to the students, wondering if they thought it was possible to figure out the energy of a tile falling from a certain height based on its starting energy and the height of the fall. The students did not respond, hinting they might not fully understand. Seeing their uncertainty, Bora chose to use visual aids to make the idea clearer. He used a drawing software on the smart board, called Antropi Teach app, and started with a blank page on the smart board (Figure 11). Bora then imagined a situation where a ball with 100J of energy was falling from a height of 2m. He asked the students what kind of energy the ball would have when it got to a height of 1m. After the students gave their answers, Bora confirmed that the ball would have both moving and stored energy at that moment.

By asking for their thoughts and validating their responses, Bora made sure the students were taking an active part in the learning and reinforcing their grasp of moving and stored energy [Understanding students' learning needs; using basic ICT tools]. This observation underlines Bora's skill in identifying his students' learning

difficulties. Bora demonstrates a proficiency level consistent with simple adoption in his use of Antropi Teach to enhance the learning process. His skillful integration of visual aids and interactive elements primarily focuses on information presentation and understanding students' knowledge to support their learning. While Bora effectively employs that ICT tool to engage students and address learning challenges, his approach aligns more closely with basic ICT tool utilization. This level of proficiency contributes to creating an engaging learning environment and reinforces student comprehension.

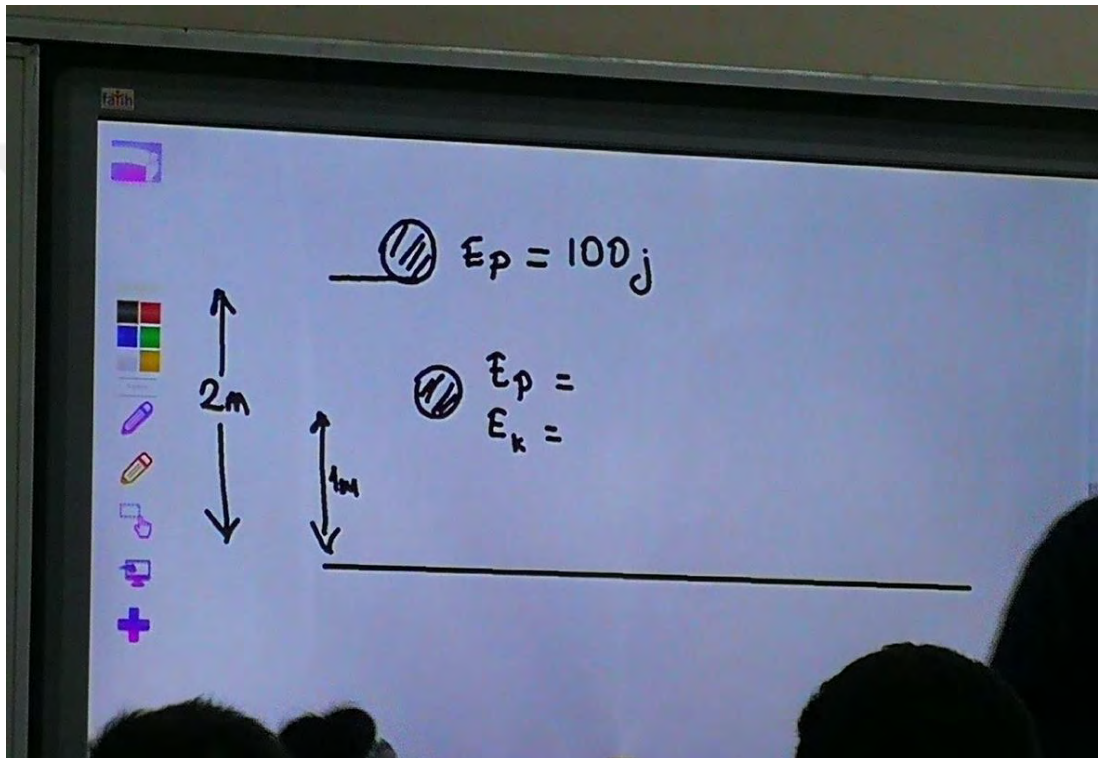


Figure 11. The image of Bora's markings made with Antropi Teach application on the smart board

Overall, Bora's proficiency level in the subdimension of understanding students' learning needs was assessed as simple adoption. This conclusion is based on his quick response to the students' silence during an observed class session, demonstrating his commitment to facilitating an engaging learning environment. By introducing visual aids and encouraging active student participation, Bora effectively supported their understanding and extended their knowledge on the subject [Understanding students' learning needs; using basic ICT tools]. Furthermore, insights from interviews with

Bora also underscore his awareness of the importance of student involvement and his dedication to evaluating and improving their understanding. These pieces of evidence collectively highlight Bora's capacity to identify and address students' learning gaps, especially in situations where their responses indicate a lack of comprehension.

4.1.2.1.2. Assessment practices

In this subdimension, the data was analyzed through classroom observations and semi-structured interview to gain valuable insights into Bora's proficiency in using ICT tools for formative assessment processes. This subdimension focuses on teacher's diverse ICT-based formative assessment practices for gauging student learning, encompassing various strategies to measure and respond to students' understanding of the content being taught. The codes used represent the proficiency levels reflecting how effectively the teacher assesses students' learning during the teaching based on these aspects. The evidence related to these practices were categorized into the following codes; no use of ICT, using ICT for in-class formative assessment, using ICT for out-of-class formative assessment, and using comprehensive ICT tools enabling product/model design. After providing detailed examples of the teacher's practices for the available codes, it can be said that Bora's proficiency level in terms of understanding assessment practices was assessed as simple adoption level.

Bora indicated that he uses both non-ICT and ICT resources to assess his students in relation to assessment practices aspect. For instance, when asked about the students having a hard time with problem-solving, he implied that he might resort to more traditional strategies to monitor their progress in learning by saying *"So, I think it would be a bit wrong to say that I only did these things, especially with digital content."* This suggests that Bora may occasionally face challenges in assessing his students solely through the use of ICT tools [Assessment practices; No use of ICT], suggesting a minimum level of proficiency in terms of assessment practices.

Nonetheless, Bora expressed that he is able to use plenty of ICT tools for formative assessment in the classroom. For example, he mentioned, *"There are pdf documents, for example, in the form of questions and lecture notes, I use them"*, and he also stated, *"... matched questions, fill-in-the-blank questions, I solve them, but other than that, I use z-books. Z-books are digital content books, you know. We wrap up the unit by*

solving plenty of questions from these z-books.” These statements exemplify some of the ICT tools he utilizes in the class [Assessment practices; using ICT for in-class formative assessment]. Bora’s proficiency in this example is in alignment with the simple adoption level since he primarily utilizes basic ICT tools for in-class formative assessment purposes.

In line with his statements, observation data showed further evidence for Bora’s in-class formative assessment practices. During the observation of the one of his classes (Observation of Bora’s 2nd class session), it was evident that Bora frequently used such ICT tools for in-class formative assessment purposes. For instance, Bora opened a test from the online learning platform Morpa on the smart board screen, related to the relationship between mass and weight subtopic. In this test, fill-in-the-blank questions and true-false questions were observed [Assessment practices; using ICT for in-class formative assessment]. The students were asked to approach the smart board to solve these questions in order. Similarly, Bora had his students solve exercise questions presented in another learning platform, EBA, regarding the topic of physical work. One of these questions was a short-answer open-ended question, asking whether a given case involved physical work or not. The teacher selected one student to provide her response by typing it into a box and then asked her to explain the reason for her answer verbally [Assessment practices; using ICT for in-class formative assessment]. Likewise, he presented multiple-choice questions related to this topic and had the students answer them [Assessment practices; using ICT for in-class formative assessment]. These are just a few examples of Bora’s frequent use of ICT tools during his classes, which reflects his proficiency at the simple adoption level, primarily utilizing basic ICT tools for in-class formative assessment purposes.

Furthermore, Bora utilized these exercise questions for multiple purposes. In line with this, it was observed that he engaged the students in identifying the type of energy observed in various examples presented through an animation on a different learning platform called Derslig (Observation of Bora’s 5th class session). These examples included a flying bird, a tree swaying in the wind, and water flowing from a waterfall. Upon completing the animation, Bora proceeded to deliver additional explanations regarding the different types of energy. To reinforce the students’ understanding, he then presented two short exercise questions. Rather than having the students solve

these questions independently, Bora took the initiative to explain the solutions himself [Assessment practices; using ICT for in-class formative assessment]. This deliberate approach suggests that Bora aimed to provide a clear and comprehensive explanation while demonstrating the problem-solving process, ultimately ensuring the students' comprehension.

Additionally, there is limited evidence suggesting the implementation of Bora's out-class formative assessment practices in his classes. For instance, after showing an animation on friction force to his students (Observation of Bora's 9th class session), Bora mentioned his intention to send an online test to their EBA accounts and check their answers in the next class. In the subsequent class, Bora reminded the students about the test and accessed the test report on the smart board by logging into his EBA account. Upon reviewing the report, he discovered that only six students had completed the test with an overall achievement ratio of 72%. Bora initiated a discussion with the students, inquiring why the others had not completed the test. He then encouraged them to complete the tests on the EBA platform and proceeded to address the most incorrectly answered questions during the class. This particular instance serves as the only evidence of Bora's employment of out-class formative assessment [Assessment practices; using ICT for out-of-class formative assessment]. Based on this example, Bora demonstrated a proficient use of online learning platforms, indicating a relatively higher level of proficiency.

Furthermore, the interview record supports Bora's this ability to effectively utilize such tools. He explains his use of out-class assessments as:

For example, we can send [homework] them from EBA. We can send worksheets, [later] we can check and get reports of the results. There are also teacher-specific questions [tests], for example. We can send those questions that students do not have access to.

Bora's explanation of sending homework, worksheets, and teacher-specific questions through platforms like EBA and analyzing the results demonstrates his proficiency in leveraging ICT tools for assignments and assessments outside the classroom [Assessment practices; using ICT for out-of-class formative assessment]. This emphasis on his utilization of ICT tools for out-of-class formative assessments underscores his proficiency in this aspect, suggesting infusive application level. While

evidence suggests Bora's capability in using ICT tools for out-of-class formative assessments, the greater prevalence of evidence for in-class assessments may indicate a lower proficiency level, possibly at the simple adoption stage.

Overall, Bora's proficiency level in terms of assessment practices can be assessed as simple adoption. While he incorporates both non-ICT and ICT tools for assessing students, there is limited evidence of his utilization of out-of-class formative assessment practices. Bora recognizes the importance of traditional strategies in tracking learning progress and occasionally faces challenges in relying solely on ICT tools for assessment. Yet, his skillful use of ICT tools for classroom-based formative assessment stands out due to his regular use of online tests and practice questions. This shows his skill in using technology for evaluating student understanding within the class setting. In addition, Bora's use of practice questions for strengthening knowledge and his ready-to-act way of explaining solutions demonstrate his dedication to confirm student understanding. Although the evidence at hand is not sufficient to rate Bora's proficiency as high when it comes to using ICT tools for out-of-class evaluation practices, his proficiency in in-class formative assessments is notable.

Table 10. The proficiency levels of Bora in assessment

Name of the Subdimension/Dimension	Proficiency Level
Understanding the students' learning needs	Simple adoption
Assessment practices	Simple adoption
ASSESSMENT	Simple adoption

To sum up, Bora's proficiency level in both subdimensions of the assessment dimension consistently falls within the simple adoption level as can be seen from Table 10. In the subdimension of Understanding students' learning needs, Bora demonstrates his ability to quickly respond to students' learning gaps, fostering an engaging learning environment through the use of basic ICT tools. In terms of the subdimension of Assessment practices, he incorporated both non-ICT and ICT tools for assessing students, although there is limited evidence of his utilization of out-of-class formative assessment practices. Bora recognizes the importance of traditional strategies in

tracking learning progress and occasionally faces challenges when relying solely on ICT tools for assessment. Regarding the overall assessment dimension proficiency level, Bora's proficiency level was determined to be simple adoption. This decision is rationalized by the collective evidence in the subdimensions, where his use of ICT tools primarily falls within this level. While there were occasional hints of potential higher proficiency levels, the limited evidence supporting these claims suggests that Bora's approach predominantly aligns with criteria of simple adoption level.

4.1.2.2. TPACK-P Proficiency Level for Planning and Designing

Bora's TPACK-P proficiency in planning and designing was assessed using the rubric that encompassed three subcategories. These subcategories, namely class planning, representations, and teaching methods, were derived through a careful examination and coding of the data. The rubric provided a structured framework for evaluating Bora's TPACK-P proficiency in planning the class, utilizing representations, and employing teaching methods/techniques within the context of ICT integration in science education.

4.1.2.2.1. Planning the Class

In this subdimension, the data was analyzed through classroom observations and semi-structured interview to gain valuable insights into Bora's proficiency in planning the class and effectively utilizing ICTs to support teaching and learning, encompassing the preparation and organization of instructional activities, setting educational goals, and aligning them with technology integration. The codes used represent the proficiency levels reflecting how effectively the teacher aligns technology with educational goals and instructional activities based on these aspects. The evidence related to these were labelled as following codes; non-ICT goal setting, using ICT to support teaching, using multiple ICTs to support learning science, and using multiple ICTs to support learning of and about science. After providing detailed examples of the teacher's practices for the available codes, it can be said that Bora's proficiency level in terms of planning the class was assessed as lack of use level.

In terms of planning the class aspect, Bora demonstrates a conscious approach to designing his classes by refraining from using ICT tools under certain circumstances,

aligning with his teaching goals. He specifically mentioned that he disregards the use of ICT tools when the emphasis is on solving more exercise questions, particularly in the upper grades preparing for the national high school entrance exam. He stated,

For example, since they are preparing for the exam, especially in the 8th grade, they need to spend more time solving questions, students need to get familiarized [with] the [different] types of questions. In such cases, for example, showing digital content wastes time. [If I'd use them] for example, there isn't much time left for solving questions.

This indicates that he designs his classes in a more traditional manner without incorporating ICT tools [Planning the class; non-ICT goal setting]. Consequently, it is reasonable to assert that Bora's TPACK proficiency level is not high due to his tendency not to use ICT tools due to in contexts where time constraints and the traditional approach to question-solving take priority.

Similarly, there was further evidence during the interview that seemed to suggest a lower proficiency level for Bora. When responding to the question about the goals he expects his students to achieve in his ICT-infused classes, Bora states:

First of all, our goal is to have all the achievements learned by the students. We need to check whether all the gains in the curriculum have been learned. But there is also this: We also provide training. We want students to grow up as characters as well. I am trying to emphasize these points in the content I have chosen. One of the issues that I care about is that students successfully learn implicit learning outcomes. For example, while looking at the Süleymaniye Mosque in the video I opened on the properties of sound, students also learn about Mimar Sinan. The Ministry wants these to be learned and emphasized in the lessons, and I believe it is necessary.

In these statements, there is evidence indicating Bora's proficiency level in terms of planning science classes. For example, he emphasizes, "*First of all, our goal is to have all the achievements learned by the students. We need to check whether all the gains in the curriculum have been learned.*" This highlights Bora's focus on planning and designing class activities to ensure comprehensive learning outcomes without relying solely on ICT tools. Bora's emphasis on ensuring comprehensive learning outcomes and checking the curriculum gains suggests that he may prioritize a holistic approach to teaching that goes beyond relying solely on ICT tools [Planning the class; non-ICT goal setting], suggesting his lack of use level of proficiency.

Surely, this does not mean that he never uses ICT tools. Rather, it suggests that Bora

understands the need to consider different teaching methods, including non-ICT ones, to reach the learning goals. Accordingly, there is one piece of evidence that indicates Bora has higher proficiency in terms of planning his classes. For example, Bora says *“On the one hand, we try to train students who know how to access information, and the digital content we use helps them a lot.”* This indicates his proficiency in utilizing ICT tools as a support mechanism in teaching and fostering students’ information retrieval skills [Planning the class; using ICT to support teaching]. Despite this proficiency in supporting information access, there is no explicit evidence in the given statements to support Bora’s proficiency in using multiple ICTs to support learning science or using multiple ICTs to support learning of and about science.

Overall, Bora’s proficiency level in planning the class was assessed as lack of use due to his tendency to refrain from using ICT tools in certain contexts where the emphasis is on traditional teaching methods, such as solving exercise questions, especially when preparing students for national exams. This suggests that he primarily adheres to a more conventional teaching approach, focusing less on technology integration for instructional purposes. Nonetheless, he does understand the significance of utilizing ICT tools to support information access in teaching. However, there is limited evidence to indicate his proficiency in using multiple ICTs to support various aspects of science learning beyond information retrieval.

4.1.2.2.2. ICT Representations

In this subdimension, the data was analyzed through classroom observations and semi-structured interview to gain valuable insights into Bora’s proficiency in utilizing ICT representation during teaching. The codes used represent the proficiency levels reflecting how effectively the teacher integrates ICT representations into his instructional practices. The evidence related to these were labelled as following codes: non-ICT representations, visualization and motivation enhancement, interactive learning support, and scientific exploration support. After providing detailed examples of the teacher’s practices for the available codes, it can be said that Bora’s proficiency level in terms of ICT representation was assessed as simple adoption level.

With respect to ICT representations used in his class, Bora used lots of representations in his class. However, there were instances that he also used non-ICT representations.

For example, it was observed in one of his classes that Bora used to stop the animation from time to time and explain the direction of the gravitational force in one of his lectures in which he taught the gravitational force to his students (Observation of Bora's 2nd class session). Afterwards, he showed his students the physical dynamometer he brought with him to the lesson [ICT representation; non-ICT representation]. He explained verbally how gravity affects mass and how weight is calculated without using formulas. In this instance, Bora employed non-ICT representations, specifically a physical dynamometer, to illustrate the effects of gravity on mass. Actually, this highlights his versatile teaching style, utilizing various tools to convey scientific concepts, at times favoring non-ICT representations over appropriate ICT alternatives.

There are instances in Bora's teaching practice where he used both non-ICT and ICT representations together. For instance, in another class taught by Bora (Observation of Bora's 8th class session), the concept of friction force was introduced to the students through the use of an animation. Based on the observation records, he paused the animation and posed a question to the students regarding why the ball, which appeared to be thrown quickly in the animation, eventually slowed down and came to a stop [ICT representation; visualization and motivation enhancement]. After gathering a few responses, Bora proceeded to take a piece of paper and a pen, dropping them from a height. As the students observed the pencil falling to the ground and moving a little, and the paper descending slowly, Bora inquired why they believed the objects stopped moving. The students attributed the pencil's descent to friction with the ground, whereas those who noticed the paper's gradual fall mentioned that it was due to friction with the air [ICT representation; non-ICT representation]. Based on these observational data, Bora's proficiency in employing ICT representations in his class appears to remain at the simple adoption level. Although he incorporates both ICT and non-ICT representations in his teaching, the examples provided suggest a relatively straightforward approach rather than a sophisticated integration of technology. The use of physical objects and live demonstrations, though valuable in certain contexts, indicates a limited utilization of ICT representations for better visualize abstract topics such as gravity, aligning with the simple adoption criterion. Notably, the classroom observations indicated that Bora utilized lots of ICT representations in his teaching,

suggesting his proficiency level falls within simple adoption level. For example, Bora used videos from the classroom's learning management system to introduce different forms of potential energy (Observation of Bora's 7th class session). To add to the visual aids, he used the Antropi Teach app to present a scenario of a ball with a set amount of energy on a blank smart board page. These examples show Bora's effort to use ICT tools to support students' understanding by providing visual and interactive elements. However, it seems that Bora's use of ICT tools in teaching mainly aimed to boost visualization, not necessarily used extensively for other teaching purposes [ICT representation; visualization and motivation enhancement]. Thus, Bora's proficiency in employing ICT representations for visualization appears to be at the simple adoption level.

Keeping with this, Bora's comments during the interview offer helpful details about his use of ICT tools and how he includes lecture notes in their teaching style. According to Bora,

Other than that, there are lecture notes that I sometimes use. Sometimes in slide form, sometimes in pdf form. But I would never teach the class entirely with them. I include it in a part of my lesson, I make variations all the time.

This acknowledgment highlights Bora's recognition of digital lecture notes as ICT representations. He utilizes these notes as supplementary resources, selectively incorporating them to enhance instruction. This approach demonstrates his ability to effectively utilize ICT representations as supportive tools rather than relying solely on them for instruction [ICT representation; visualization and motivation enhancement].

Overall, although it is important to note that the overall proficiency level of Bora in utilizing ICT representations did not go beyond the level of simple adoption despite his utilization of various ICT representations. While there were instances of using ICT tools for visualization and motivation purposes, the use of non-ICT representations, such as physical models or diagrams, might suggest a lower level of proficiency in the context of TPACK-P. Therefore, based on the evidence presented, it can be inferred that his proficiency in utilizing ICT representations was primarily focused on enhancing visualization, suggesting simple adoption level of proficiency.

4.1.2.2.3. Teaching methods/techniques

In this subdimension, the data was analyzed through classroom

observations and semi-structured interview to gain valuable insights into Bora's proficiency in instructional strategies with varying degrees of student-centeredness when using ICTs. This subdimension assesses to teacher's preferences regarding the centeredness of teaching. The evidence related to these approaches were labelled with the following codes: completely teacher-centered, mainly teacher-centered, mainly student-centered, and completely student-centered. After providing detailed examples of the teacher's practices for the available codes, it can be said that Bora's proficiency level in terms of teaching methods/techniques was assessed as simple adoption level.

With regards to teaching methods/techniques, the data was examined to assess Bora's TPACK-P proficiency. According to the findings, it is evident that Bora predominantly employs a teacher-centered approach when delivering the content to his students. Accordingly, the classroom observations revealed that the students in Bora's class typically remained silent and only spoke when prompted. They were seldom observed engaging with ICT tools or actively participating in activities in front of the smart board. Despite Bora's preference for using basic questioning techniques during content delivery, student interaction with the ICT tools was minimal. Instead, he primarily utilized the smart board, particularly during formative assessment processes. For instance, it was observed that Bora presented a question to the students involving three identical cars with speeds of 240 km/h, 260 km/h, and 220 km/h, respectively (Observation of Bora's 5th class session). The students were asked to rank the energy levels of these cars. Bora himself collected the students' answers and provided the correct answer by dragging and dropping it himself on the screen. In another instance, a true-false branched question was presented to the students. They were tasked with finding the correct output based on the given answers. Bora facilitated the activity by having the students take turns reading each statement aloud while he himself marked the corresponding answers. Upon clicking the 'check answers' button, he saw that the indicated answer was incorrect. These observations indicate that students in Bora's class could not find opportunities to interact with ICT tools or actively participate in learning activities [Teaching method/technique; completely teacher-centered]. This lack of involvement suggests that Bora's proficiency in ICT-infused teaching strategies seems at lower levels. Despite relying on basic questioning methods, the emphasis remains on the teacher's use of the smart board during formative

assessments, reinforcing a teacher-centered approach.

In line with these, the interview data support his teacher-centered teaching style. Although Bora expressed a desire to encourage student participation in class activities during the interview, the data suggests that his planning and design of science class does not effectively support this purpose. To illustrate, Bora shared his thoughts on different teaching methods and stated,

It [cooperative learning] is actually a method recommended by our ministry. That is, to create groups of students in the classroom, bring various materials and make them do activities, and enable them to learn by experience. This is a very successful method, actually, a good method.

This quotation highlights Bora's awareness of cooperative learning as a recommended teaching method that promotes student engagement and experiential learning. However, it also emphasizes his departure from this approach in favor of his own preference for the constructivist education model. This preference indicates his inclination towards a more teacher-centered approach [Teaching method/technique; mainly teacher-centered], where he assumes a central role in delivering content rather than fostering student collaboration and active participation. Furthermore, Bora continued,

... Instead, I preferred the constructivist education model in the classrooms. The reason for this is that we provide exam-oriented training. ... In cooperative learning; [the student] doesn't actually have to worry about anything, he won't have much test anxiety. It is more important that young people learn by making gains there.

Here, Bora acknowledges that his preference for the constructivist education model is driven by the exam-oriented nature of the educational system. This suggests that his focus is primarily on delivering content and preparing students for exams, rather than creating an interactive and student-centered learning environment. By prioritizing exam outcomes over student engagement, Bora's teaching approach remains teacher-centered and may limit opportunities for students to actively participate and construct their own knowledge [Teaching method/technique; completely teacher-centered]. At first glance, it is understood from his statements that Bora appears to have a sufficient ability to use more student-centered instructional strategies. However, Bora further explains,

I don't apply it [cooperative learning] very much, but when I make assessments with a constructive education model, it can be a little easier for me to notice what they have learned and what they have not learned, since I put the students one by one on the smart board while solving questions from z-books and when solving assessment questions with various software in classes.

Consequently, Bora's assessment approach reflects a teacher-centered perspective, focusing mainly on evaluating individual student performance rather than fostering collaborative and interactive learning experiences. By utilizing the smart board and software tools, Bora can evaluate students' problem-solving abilities and comprehension of the subject matter. Nevertheless, this approach might limit students' chances to interact with their classmates, work together to solve problems, and engage in shared learning experiences [Teaching method/technique; completely teacher-centered]. Moreover, Bora's statements suggest that he has a limited understanding of constructivism, as he mostly associates it with exam-focused training and individual assessments. This indicates that he might not fully grasp the key principles of constructivism, such as the importance of student-centered learning, collaboration, and active participation. Bora's preference for a constructivist educational model centered around exams indicates a potential misunderstanding of constructivism's goals and principles. Thus, these pieces of evidence imply his proficiency level remains at a basic level since Bora generally adopts one-way communication when teaching with ICT.

On the other hand, the data collected from Bora's teaching approach exhibits a shift towards a less teacher-centered. In several observed lessons, he initiated class activities with the use of digital media, such as videos, animations, and images displayed on the smart board. For example, in one observation session (Observation of Bora's 7th class session), he initiated a lesson on energy conservation using an animation on the Morpa learning platform. The animation illustrated a tile swaying and eventually falling in the wind. Following this sequence, Bora paused the animation and engaged the students in a question-and-answer session. He prompted the students to consider the energy possessed by the tile before it fell, eliciting their responses. After receiving several answers, he clarified that the tile possessed maximum gravitational potential energy but zero kinetic energy at that moment. Continuing the discussion, he further explored what happened when the tile began to fall, encouraging additional responses from the students. Bora explained that as the tile descended, its gravitational potential

energy gradually decreased while its kinetic energy increased. In this moment, he asked another question to the students, wondering if all the potential energy that decreased was converted into kinetic energy. After a brief pause for thinking, a student replied, pointing out that some of the potential energy was lost due to air friction, which resulted in the energy transforming into heat. Lastly, he wrapped up the session by summarizing the input given by the students as a whole. Based on this observation, it is evident that Bora prompted students to contemplate the energy changes of the falling tile and encouraged them to provide answers. This interactive approach allowed students to actively participate in the learning process. Bora's shift towards a less teacher-centered approach is evident in his use of open-ended questions and the incorporation of students' responses into the lesson [Teaching method/technique; mainly teacher-centered]. Consequently, Bora's teaching method can be characterized as mainly teacher-centered as he combines pedagogical strategies aimed at enhancing student motivation and understanding of the content when incorporating ICTs, allowing for some interaction with students but with the teacher still leading.

This approach was further exemplified in another observation of Bora's class, where he introduced a new video on potential energy through the classroom learning management system (Observation of Bora's 6th class session). To initiate the discussion, Bora requested students to provide examples of potential energy, receiving a few responses. Subsequently, he started the video and paused it when examples of gravitational potential energy appeared. Taking advantage of this moment, Bora connected the current topic to a previous lesson by asking the students, 'In the previous lesson, we discussed the factors influencing kinetic energy. So, what might gravitational potential energy depend on?' Bora then proceeded to verify and correct student responses, including factors such as height and weight, before explaining that gravitational potential energy primarily depends on an object's height and mass. Upon this observation, it is reasonable to state that his reliance on videos, animations, and images displayed on the smart board, as well as his control over the question-and-answer sessions, indicates a limited integration of technology and pedagogy to create a more student-centered learning environment [Teaching method/technique; mainly teacher-centered]. Instead, Bora maintained a more traditional approach where he primarily delivered information and guided the discussion. Therefore, his proficiency

level remains at simple adoption level due to limited allowance of student interaction.

Overall, Bora's teaching methods and techniques are predominantly teacher-centered, with students often participating passively in the learning process. However, there were few instances where Bora incorporated more student-centered methods, particularly when introducing design tasks. Despite these exceptions, his overall teaching approach emphasizes enhancing content understanding while maintaining teacher-led interactions. As a result, Bora's proficiency level in teaching methods and techniques is assessed as lack of use, reflecting his tendency towards completely teacher-centered approaches.

Table 11. The proficiency levels of Bora in planning and designing

Name of the Subdimension/Dimension	Proficiency Level
Planning the class	Lack of use
ICT Representations	Simple adoption
Teaching method/technique	Lack of use
PLANNING and DESIGNING	Lack of use

To sum up, it is evident that Bora's proficiency level in the planning and designing dimension consistently falls within the lack of use category as seen in Table 11. In terms of planning the class, Bora's emphasis on non-ICT goal setting particularly in contexts prioritizing traditional teaching methods, indicates his lowest proficiency level. Moreover, his primary focus lies in the utilization of ICT representations to enhance visualization the concepts or phenomena within the class. However, his teaching approach leans toward completely teacher-centered teaching methods rather than more student-centered approach. Although his abundant use of ICT representation, which indicates his simple adoption level of proficiency, the reason for categorizing his overall planning and designing dimension as lack of use is primarily due to the dominance of traditional, non-ICT teaching methods in specific contexts. Despite his capability to employ ICT representations for visualization, the instances where he reverts to traditional teaching approaches, such as focusing on non-ICT goal

setting, create an imbalance that leads to the lack of use assessment. As such, Bora's overall proficiency in planning and designing the class reflects his limited integration of ICT tools for instructional purposes, placing him firmly within the lack of use proficiency level.

4.1.2.3. TPACK-P Proficiency Level for Enactment

In this section, the analysis of the observation data and interview records aimed to examine the teacher's level of TPACK-P proficiency when it comes to implementing technology in instruction. The focus was on three specific areas: guiding the use of ICT, encountering technical challenges, and integrating ICTs into teaching contexts. The data provided valuable insights into Bora's competence in effectively incorporating technology during instructional delivery.

4.1.2.3.1. ICT guidance

In this subdimension, the data was analyzed through classroom observations and semi-structured interview to gain valuable insights into Bora's proficiency in guiding in utilizing ICT tools for science instruction. This subdimension focuses on the quality of ICT guidance provided by the teacher. The evidence related to this guidance were labelled with the following codes: insufficient guidance, verbal and visual instruction, learning facilitation with practice, and extensive scientific thinking and concept building. After providing detailed examples of the teacher's practices for the available codes, it can be said that Bora's proficiency level in terms of ICT guidance was assessed as lack of use level.

Regarding ICT guidance, Bora did not provide a clear perspective on his ability to guide his students in familiarizing themselves with and effectively using ICT tools in science classes based on the interview data. Although he mentions that he provides opportunities for his students to interact with smart boards and other tools, he did not specify how he facilitates these interactions. His statement,

I give every student the right to speak, I make sure to put everyone on the board at least once a week. Then I can observe the level of their learning from their answers and sometimes even from their eyes.

implies that students may have the opportunity to seek assistance if they encounter

difficulties in using ICT tools. However, Bora's lack of clear guidance and weak feedback mechanism substantially suggests insufficient support in effectively using these tools [ICT guidance; insufficient guidance]. Based on this evidence, Bora's proficiency level in ICT guidance can be characterized as insufficient guidance, reflecting a need for more structured and clear instruction in assisting students with ICT tool utilization.

Consistent with this, the classroom observation did not indicate a clear example of Bora's ICT guidance to his students. This may have resulted from his teacher-centered teaching approach. Nevertheless, although Bora mainly uses different ICT tools such as enhanced learning materials and exercise questions from various learning platforms, z-books, and drawing applications himself, rather than enabling his students to use them, it can indicate a slightly higher level of proficiency in ICT guidance. The use of a diverse range of ICT tools suggests that Bora actively incorporates technology into their instructional practices, which can enhance students' engagement, interaction, and learning experiences. However, the scarcity of his guidance on use of ICT while teaching was not clearly observed. Thus, the available data reveals that Bora's proficiency does not seem to be higher than insufficient guidance.

Overall, Bora's proficiency level appears to be categorized as lack of use in terms of ICT guidance. The evidence suggests that he does not provide clear and structured support to help students become proficient in using ICT tools in science classes, which can be attributed to his predominantly teacher-centered teaching style. While Bora actively integrates various ICT tools into his teaching, the classroom observations do not reveal significant guidance offered to students on utilizing these tools. Although his use of technology enhances student engagement, interaction, and learning experiences, the overall evidence supports the classification of his proficiency as insufficient guidance at the level of lack of use.

4.1.2.3.2. Struggling with technical issues

In this subdimension, the data was analyzed through classroom observations and semi-structured interview to gain valuable insights into Asaf's proficiency handling technical issues during his teaching. The evidence from the interview data related to this guidance were labelled with the following codes: unable to proceed with the

topic/class, inadequate technical troubleshooting and backup strategies, seeking spontaneous ICT-based solutions or delaying, and continuing the class calculatedly without interrupting. After providing detailed examples of the teacher's practices for the available codes, it can be said that Asaf's proficiency level in terms of struggling with technical issues was assessed as infusive application level.

Regarding struggling with technical issues, Bora confidently asserts his ability to overcome such challenges during his teaching. He states, *"Since I am a mentor teacher, I am able to solve most of the problems."* At first glance, Bora's claim suggests a very high level of proficiency. However, this self-confidence does not align with the rubric criteria. For example, he demonstrates adaptability and problem-solving skills by utilizing alternative options when faced with technical difficulties. Bora states, *"On rare occasions, I continue the lesson by distributing printed copies. But only if I have these, I can do it."* This shows that Bora has backup strategies in place, such as having printed materials available, to ensure the class can continue uninterrupted even in the absence of technology. However, it is important to note that the effectiveness of these solutions may be limited by the emphasis on the availability of printed materials, which ultimately restricts his skills in overcoming technological issues [Struggling with technical issues; seeking spontaneous ICT-based solutions or delaying]. This leads to lower his proficiency than highest level, where he successfully overcome technical problems without interrupting the class. Thus, his proficiency level can be categorized as infusive application based on these pieces of evidence.

Additional examples shed light on Bora's proficiency level concerning struggling technological issues. For instance, when confronted with a situation where a digital copy of a textbook was unavailable on the EBA platform as reported by his students (Observation of Bora's 9th class session), Bora did not promptly address the issue or offer an alternative solution. Instead, he informed the students that he would bring the digital copy in the next lesson rather than providing it from his flash drive or making a quick web search to acquire it [Struggling with technical issues; seeking spontaneous ICT-based solutions or delaying]. This response indicates a deficiency in his technical troubleshooting skills and backup strategies to handle the situation effectively. Consequently, Bora's proficiency level in terms of technical troubleshooting and backup strategies appears to be at infusive application level.

On the other hand, there is further evidence indicating that Bora's ability to handle simple technical challenges is more sufficient. In his statement, *"For example, in case of internet disconnection, I turn to different alternatives. For example, I switch to the textbook or other documents on my flash drive."* This implies that Bora can move on to digital content from available sources to address technical issues that may interrupt his teaching. However, during observations of his teaching, Bora rarely referred to the textbook, which suggests that his tendency to seek alternative digital solutions is more like seeking spontaneous ICT-based solutions [Struggling with technical issues; seeking spontaneous ICT-based solutions or delaying], indicating a proficiency level closer to infusive application rather than the highest level.

Overall, Bora's proficiency level can be categorized as infusive application in the subdimension of struggling with technical issues. While he asserts confidence in overcoming technical challenges, the evidence suggests a proficiency level that aligns with seeking spontaneous ICT-based solutions or delaying. Bora demonstrates adaptability by utilizing alternative options when facing technical difficulties, such as turning to printed materials in rare instances. However, his tendency to seek digital solutions is more akin to seeking spontaneous ICT-based solutions, and his response to specific technical issues may delay effective resolution. Overall, Bora's proficiency level in handling technical challenges leans towards infusive application rather than the highest level of proficiency.

4.1.2.3.3. Infusing ICTs into teaching contexts

In this subdimension, the data was analyzed through classroom observations and semi-structured interview to gain valuable insights into Bora's proficiency strategically integrating ICT tools into his teaching practices to enhance the overall learning environment. This subdimension focuses on a range of approaches and strategies employed by the teacher to seamlessly incorporate ICTs into instructional contexts, ultimately contributing to an enriched teaching and learning experience. The codes used reflect Bora's proficiency levels in terms of infusing ICTs into teaching contexts, which highlight the effectiveness and depth of his integration. These proficiency levels encompass the belief that ICTs offer no contribution to teaching practices, the use of basic and convenient ICT tools for instructional enhancement, flexible and selective

management of ICTs for instructional purposes, and skillful use of technology to foster student independence. After providing detailed examples of the teacher's practices for the available codes, it can be said that Bora's proficiency level in terms of infusing ICTs into teaching contexts was assessed as infusive application level.

When assessing Bora's proficiency in infusing ICTs into teaching contexts, it is crucial to examine his beliefs and practices concerning the role and impact of technology in teaching methods. Remarkably, Bora mentioned a disadvantage of infusing ICT tools into science teaching during the interview as follow:

If we think from the student's point of view, it does not seem to have a disadvantage, but there is also this: For example, he watches the light bulb connection experiment on the smart board and activates the mechanism by touching the screen. But now, does the experiment he does here virtually feel the same, does it teach at the same level, by connecting real bulbs with real wires? I don't think so. That's why I think that sometimes ICT tools prevent this, at least in terms of psychomotor skills development.

Bora's statements imply a belief that technology does not contribute significantly to teaching practices. He raises concerns about the effectiveness of virtual experiments compared to real hands-on experiences, suggesting that ICT tools may hinder the development of psychomotor skills in certain cases. However, he noted that ICT-based science classes have the potential to enhance the development of psychomotor skills in students. While some aspects of hands-on, physical experimentation may be challenging to replicate through virtual simulations or digital tools, there are still opportunities for students to engage in interactive activities that promote psychomotor skill development. For example, using touchscreens, sensors, or virtual reality tools can provide students with opportunities to manipulate virtual objects, conduct virtual experiments, and engage in simulations that require motor skills. Thus, it is evident to say that Bora neglects the potential of specific ICT tools can be also develop students' psychomotor skills [Infusing ICTs into teaching contexts; belief in no contribution of ICT to teaching practices], referring to his lack of use proficiency level.

Bora's further statements imply his proficiency level would be higher in infusing technology in his teaching contexts. He describes his opinion of utilizing ICT tools during his classes as follows:

When we use ICT tools, our performance is higher ... If they understand the lessons we teach with technology opportunities, they better understand. Seeing and hearing the visual examples there rather than my speaking contributes to their understanding and learning. ICT tools also save time. For example, we save time with the experiments we do in a shorter time, which positively affects the performance of the lesson.

These highlight Bora's belief in the positive impact of ICT tools on teaching practices. He acknowledges that using ICT tools enhances performance, improves students' understanding of lessons through visual examples, and saves time, particularly evident in the efficiency of conducting experiments. While he acknowledges some benefits of using ICT tools, such as enhanced performance, improved understanding, and timesaving, his statements do not demonstrate a comprehensive understanding or utilization of ICTs to support higher-level teaching practices [Infusing ICTs into teaching contexts; enhancing teaching through basic and convenient ICT integration]. Bora's focus on the immediate benefits and convenience of ICT tools suggests a more surface-level understanding rather than a deep integration of technology for transformative teaching and learning experiences. Therefore, his level of proficiency falls short of reaching the upper levels where teachers skillfully use technology to support student independent learning and manage ICTs flexibly and selectively for student learning and instructional management.

In line with these statements, classroom observations supported Bora's infusing ICT into his classes is primarily to enhance his teaching. During the observation of teaching the changing of energies (Observation of Bora's 8th class session), he proceeded to open a new animation that depicted an object moving on a platform containing both flat and inclined surfaces (Figure 12). Utilizing the pen tool, he actively engaged the students by encouraging them to identify various energy types at different points and their associated changes. To facilitate this discussion, Bora sketched the object's shape at each point and denoted the corresponding energy type (e.g., Ep, Ep). Furthermore, he actively encouraged the participation of the entire class by seeking confirmation from the students and marking their responses accordingly. These observations underscore that Bora's primary objective in incorporating ICT tools into his classes is to improve instruction by effectively and practically utilizing these tools, thus enhancing students' engagement [Infusing ICTs into teaching contexts; enhancing teaching through basic and convenient ICT integration]. Thus, Bora's proficiency level

aligns with the simple adoption level, emphasizing his focus on enhancing teaching practices with ICT integration. Overall, contribution to teaching practices, specifically in terms of psychomotor skill development, he acknowledges some immediate benefits of ICT tools, such as Bora's proficiency in infusing ICTs into teaching contexts is characterized by a simple adoption level. While he initially expresses concerns about technology's

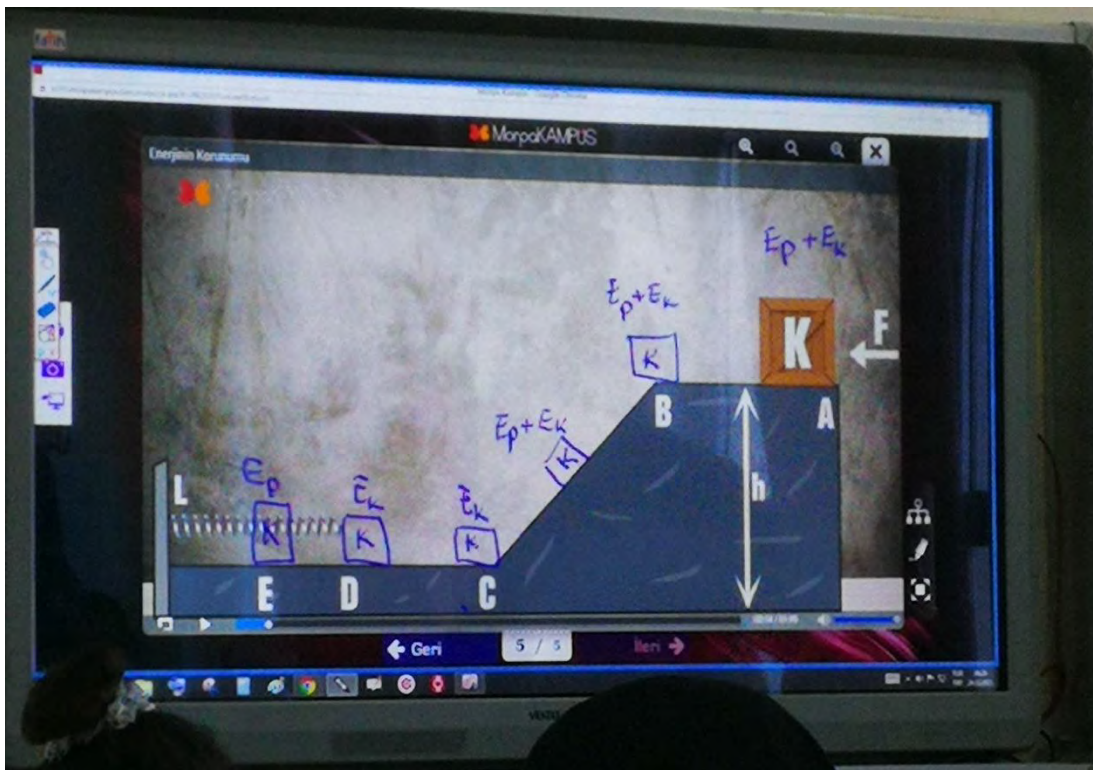


Figure 12. The image of the animation regarding change of energy and the markings Bora made on the smart board

focus remains on the convenience and efficiency of ICT tools, rather than a deeper, transformative integration for enriched learning experiences. Classroom observations support that Bora primarily uses ICT tools to enhance his teaching and improve students' engagement, aligning with the basic and convenient integration of technology. Thus, his proficiency level reflects a practical approach to ICT integration that falls short of more profound transformative practices.

To sum up, Bora's proficiency level in the enactment dimension is assessed as simple adoption.

Table 12. The proficiency levels of Bora in enactment

Name of the Subdimension/Dimension	Proficiency Level
ICT guidance	Lack of use
Struggling with technical issues	Infusive application
Infusing ICTs into teaching contexts	Simple adoption
ENACTMENT	Simple adoption

This overarching assessment is based on a comprehensive analysis of his performance across the subdimensions, which exhibit variability as seen in Table 12. In ICT guidance, Bora demonstrates insufficient support in guiding students effectively, which aligns with the lack of use level. In struggling with technical issues, while he shows adaptability and some confidence in handling technical challenges, his reliance on simple solutions leads to the infusive application level. In infusing ICTs into teaching contexts, Bora's primary objective is to enhance his teaching conveniently, reflecting basic and convenient ICT integration. This pragmatic approach to ICT usage lacks the transformative depth required for enriched learning experiences. Thus, the assessment of simple adoption takes into account the amalgamation of these findings, indicating the need for deeper and more transformative integration of ICT tools in Bora's teaching practices.

4.1.3. Case 3: Cenk

In this section, a detailed analysis of Cenk's TPACK-P proficiency levels in three educational dimensions was presented. Each dimension was explored to provide insights into the proficiency of integrating technology into pedagogical practices. These dimensions included assessment, planning and designing, and enactment.

4.1.3.1. TPACK-P Proficiency Level for Assessment

Cenk's proficiency levels in assessment were assessed by combining data from observations of his classes and semi-structured interview. The assessment dimension of the TPACK-P framework, which includes understanding students' learning needs and assessment practices, was used to analyze the data. The codes were then organized

into these subcategories, allowing for a comprehensive evaluation of Cenk's assessment proficiency.

4.1.3.1.1. Understanding students' learning needs

In this subdimension, the data was analyzed through classroom observations and semi-structured interview to gain valuable insights into Cenk's proficiency in using ICT tools to comprehend and address students' learning needs. This subdimension focuses on a spectrum of teacher's abilities and methodologies in utilizing ICT to assess their students' learning requirements, encompassing tasks such as the identification of misconceptions, determination of background knowledge for the topics to teach, and motivation-enhancing strategies. The codes used represent the proficiency levels reflecting how effectively the teacher assess students' learning needs based on these aspects. The evidence related to these needs were labelled as following codes: unable to use ICT effectively, using basic ICT tools, observing students' ICT interactions, and using LMS for understanding and structuring self-learning. After providing detailed examples of the teacher's practices for the available codes, it can be said that Cenk's proficiency level in terms of understanding students' learning needs was assessed as simple adoption level.

Regarding understanding students' learning needs, the data indicated that Cenk seems to utilize various ICT tools to meet his students' learning needs. To do this, he mentions that he could use tools containing both visual and auditory elements. He emphasized the effectiveness of using audio-visual examples through ICT tools to enhance students' understanding. As he stated, "*It becomes more permanent when they [students] see and watch these [audio-visual examples].*" Additionally, when asked about the types of examples he provides using these tools, Cenk mentioned,

Actually, I have some lessons where I draw concept maps, but I use them for starting the lesson or summarizing the lesson rather than grading. I use GitHub on my phone, I reflect it on the smart board. Children both see how I draw and learn. It seems clearer and more understandable.

These statements highlight Cenk's deliberate use of basic ICT tools to engage students visually and facilitate their comprehension of lesson content aiming to enhance students' understanding [Understanding students' learning needs; using basic ICT

tools]. While he acknowledges the effectiveness of these tools, his use is mainly focused on presenting content to facilitate student learning, and there is no indication of him actively observing or analyzing students' interactions with ICT resources to adapt his teaching.

Similarly, during the interview, Cenk shared an example illustrating the effectiveness of his teaching approach. He stated, *"For example, I can give an obvious example. One of my students couldn't understand much when I explained with lecturing. But when I did make modeling, he grasped it very well."* This highlights the significance of using modeling as a teaching method. The researcher sought further clarification, asking about the specific example. Cenk explained,

It happened when I was talking about the friction force. First, I explained it verbally, then when I showed the image and video in the modeling that I opened on the smart board, the children stated that what they watched had happened to them before, and now they understood better how frictional surfaces affect the friction force.

Cenk's use of modeling, accompanied by ICT-based visual aids, seems to allow the students to make connections with real-life experiences and gain a deeper understanding of the concept. This anecdote underscores the value of incorporating hands-on and visual elements in teaching to enhance students' comprehension and engagement [Understanding students' learning needs; using basic ICT tools]. Cenk's statements highlight that students' interactions with ICT tools are rather limited, emphasizing his proficiency level as simple adoption. He utilizes a range of materials to aid learning, such as animated content, video presentations, simulations, or hands-on experiments. This demonstrates Cenk's dedication to create more opportunities for learning and offer support, aligning with his goal of facilitating student learning. However, it is important to note that there was no direct evidence of this specific example being implemented in Cenk's classes, making the validation of these statements challenging.

Furthermore, the observations generally indicate that Cenk takes a proactive approach in leveraging ICT tools to create interactive and visually engaging learning experiences. However, during the observation of one of his classes (Observation of Cenk's 1st class session), it was observed that Cenk's use of technological tools to actively engage students appeared limited. When teaching the concept of weight, Cenk

introduced an animation that included a question about how students typically respond when asked about their weight. After collecting a few responses from the students, he explained that the confusion between mass and weight is a common misconception in daily life. Despite recognizing this misconception, Cenk's use of ICT tools primarily focused on highlighting the misconception rather than effectively diagnosing and addressing it. After briefly discussing the confusion between weight and mass, Cenk asked a few questions to assess student understanding, but the extent to which this approach effectively clarified the concept or helped students overcome the misconception was unclear. Based on these observations, it is evident to say that Cenk uses ICT tools primarily for information presentation and to highlight common misconceptions (such as the confusion between mass and weight). However, the observations indicate that the interactivity and diagnostic strategies in Cenk's use of ICT tools are limited, which implies that he may not be fully utilizing the potential of ICT tools to enhance student learning or effectively address misconceptions [Understanding students' learning needs; using basic ICT tools]. The limited interactivity and lack of clear diagnostic strategies in Cenk's use of ICT tools suggest that their potential for enhancing student learning and overcoming misconceptions may not have been fully realized.

In the classroom observations, there is evidence implying Cenk's higher proficiency level in understanding his students' learning needs. During the observation of Cenk's teaching (Observation of Cenk's 14th class session), it was noted that he observed a low response rate from the class for certain questions during a general review of the unit on Force and Energy. In response, Cenk opened the summary notes of the entire unit, stored in PDF format on their flash drive, which provided clear definitions of concepts and their relationships. He actively engaged with the students by filling in a concept map (Figure 13) that had been prepared beforehand, occasionally referring to these summaries for guidance. These observations suggest Cenk's adaptability and resourcefulness in addressing the students' low response rate and their commitment to facilitating student understanding [Understanding students' learning needs; observing students' ICT interactions]. This proactive approach indicates Cenk's ability to use ICT resources to adapt his teaching when faced with learning challenges by his students, and possibly gives him opportunities to address them.

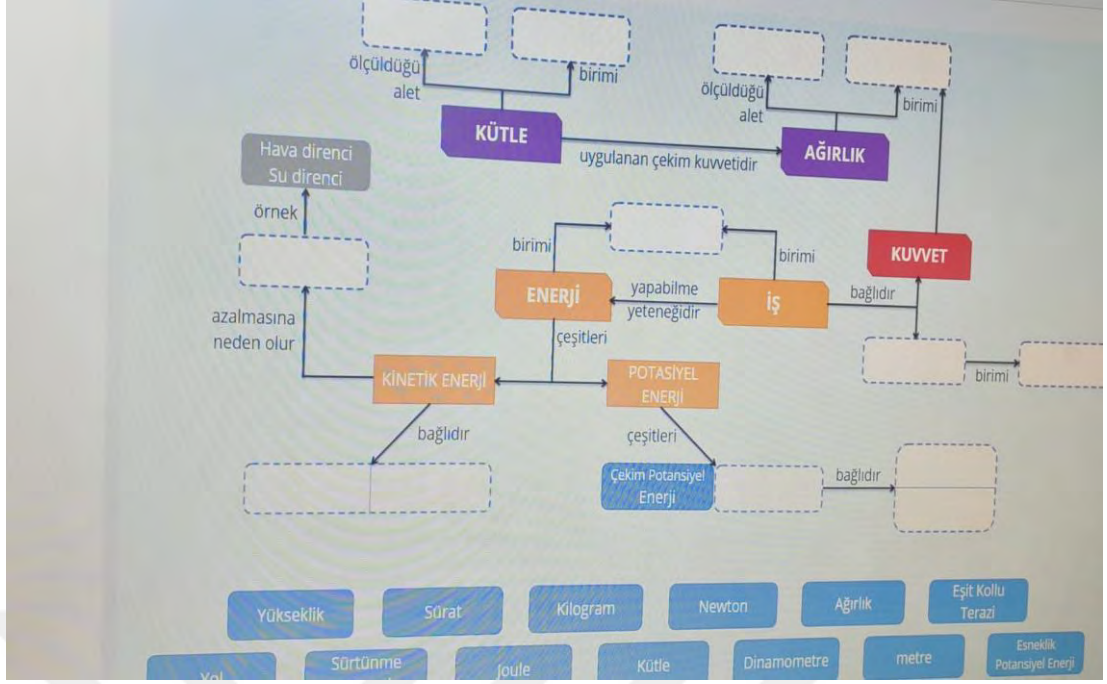


Figure 13. The image of the concept map Cenk used regarding force and energy unit on the smart board

Similarly, there seems to be evidence that Cenk’s proficiency in understanding the learning needs of his students may be at higher level considering interview data. He stated that he used various approach to determine and teach conveniently according to his students’ profile. Cenk explained his approach to utilizing ICT tools in the following statement:

This is what I do: I send assignments from EBA. Or I send assignments from WhatsApp, BIP groups. These [assignments] provide feedback for me. I want them to send me over the phone or via e-mail to my computer. I’m checking how many students from the class solved it and how many of them solved correctly. I then validate by asking how they solved some questions in the lesson. I listen to the reasons for those who did not solve or those who can’t solve. Their access to ICT tools is either non-existent or limited. But the participation of those who have limited access is good... I feel that the assignments achieve my goal.

When the researcher asked a clarifying question about how Cenk addresses learning difficulties arising from the inability to complete these assignments, Cenk confirmed, “Yes, if I notice that there are deficiencies in the subject, we dwell on those subjects a little more. I try to help them learn a little more by opening new animations, videos or, if available, simulations or experiments.” Cenk’s approach to using ICT tools for assignments is evident in his reliance on platforms like EBA, WhatsApp, and BIP

groups to send tasks to students and receive feedback. He values the ability to track students' completion and correctness of assignments, and he further engages with them by discussing how they approached specific questions [Understanding students' learning needs; observing students' ICT interactions]. Cenk's statements also reflect his awareness that not all students have equal access to ICT tools, but he observes that those with limited access still actively participate. These observations underscore Cenk's comprehension of how these tasks contribute to achieving his teaching objectives. Consequently, these statements indicate that Cenk effectively analyzes his students' learning difficulties by utilizing various ICT tools, particularly digital assessments that gives valuable feedback to him.

Additionally, Cenk makes it clear that if a topic is causing trouble for learners, that's where more attention goes. He utilizes a range of materials to aid learning, like animated content, video presentations, simulations, or hands-on experiments. This shows Cenk's dedication to create more chances for learning and offer support. His aim is to assist learners in dealing with difficulties and enhancing their grasp of the subject matter. Thus, Cenk's use of ICT tools in assignments aligns with his goal of facilitating student learning. His approach allows him to monitor student progress, address learning difficulties, and provide additional resources to enhance understanding.

Overall, based on the data collected, Cenk's TPACK-P proficiency level in terms of understanding students' learning needs remains as simple adoption level despite his consideration of ICT tool-student interactions. While Cenk does make efforts to meet his students' learning needs through the use of various ICT tools, such as audio-visual examples, concept maps, and PDF summaries, there were no clear instances where his use of technology allowed students to self-construct their learning or enabled him to observe students' interactions with those tools to understand their learning characteristics.

4.1.3.1.2. Assessment practices

In this subdimension, the data was analyzed through classroom observations and semi-structured interview to gain valuable insights into Cenk's proficiency in using ICT tools for formative assessment processes. This subdimension focuses on teacher's

diverse ICT-based formative assessment practices for gauging student learning, encompassing various strategies to measure and respond to students' understanding of the content being taught. The codes used represent the proficiency levels reflecting how effectively the teacher assesses students' learning during the teaching based on these aspects. The evidence related to these practices were categorized into the following codes: no use of ICT, using ICT for in-class formative assessment, using ICT for out-of-class formative assessment, and using comprehensive ICT tools enabling product/model design. After providing detailed examples of the teacher's practices for the available codes, it can be said that Cenk's proficiency level in terms of understanding assessment practices was assessed as infusive application level.

Regarding assessment practices, there is evidence that Cenk utilized ICT tools for formative assessments of his students both in-class and outside the classroom. This utilization of technology implies Cenk's TPACK-P proficiency, as he effectively integrates technology into the assessment process to gather valuable feedback and support student learning. During the observation of his teaching, it was evident that Cenk extensively employed ICT tools for in-class formative assessment purposes. Specifically, he utilized a variety of exercise questions, including true-false, fill-in-the-blank, matching, and multiple-choice types. For instance, in one of his classes (Observation of Cenk's 6th class session), Cenk opened the browser on the smart board, accessing the internet. Using a specific keyword, he conducted a Google search, seeking relevant resources. Eventually, a PDF document named objective comprehension test on work and energy consisting of multiple-choice questions was opened. Cenk expressed a fondness for the questions and informed the students that they would be solving some of them. The first question in the test featured an image depicting the measurement of an object's weight on both the Moon and Earth. While emphasizing that the dynamometers used were identical, the question posed a challenge to identify the option that demonstrated the weight of the object being different on Earth compared to the Moon. According to these observations, Cenk's effective use of ICT tools during the observed class session, where he employed a PDF document with challenging multiple-choice questions to engage students in interactive learning, serves as a strong example of in-class formative assessment [Assessment practices; using ICT for in-class formative assessment]. His approach aligns with a

proficiency level indicating that he skillfully uses ICT tools to assess students' learning during class, promoting an interactive and dynamic learning environment. Overall, Cenk demonstrates a proficient level of expertise in employing ICT for in-class formative assessment, as it is evident that he harnesses technology to enhance students' learning experiences and assess their understanding during classroom instruction

Likewise, in another observed session (Observation of Cenk's 12th class session), Cenk accessed a PDF document containing test questions using a USB drive. Announcing that everyone would take turns solving the test, he informed the students that they would determine who would come to the board by visiting the website www.kuracek.com and conducting a random drawing. To ensure fairness, Cenk verified the presence of students numbered 1 to 29 on the class roster. In the drawing information section of the website, he entered the number 30 and proceeded to generate a random number for each drawing. By announcing the number drawn, Cenk called the corresponding student to the board. Upon reaching the board, he instructed the student to read the question aloud, emphasizing the importance of understanding the question's cause-effect relationship. Cenk encouraged the student to explain the question, delving into the underlying cause-and-effect connections. Accordingly, the first question presented a series of five images, and the student was instructed to identify and mark the images that exemplified energy conversion. Using the pen tool, the student interacted with the images on the screen by touching them with their finger and indicating the selected ones. Upon examining these observations, Cenk demonstrated an effective approach to in-class formative assessment, reflecting his proficiency in using ICT tools for this purpose [Assessment practices; using ICT for in-class formative assessment]. He engaged the students in a dynamic activity by utilizing an interactive online tool for random student selection and question presentation. This activity allowed the selected students to not only read and comprehend the questions but also articulate their understanding of cause-and-effect relationships, as well as engage with visual materials to demonstrate their comprehension. Thus, Cenk fostered an environment that promoted active student involvement and the development of key skills related to in-class formative assessment, indicating his proficiency at this level.

Beside the observational evidence of Cenk's use of ICT tools for in-class formative

assessment, his statements supported what was observed in his classes. Based on the interview data, Cenk explains his approach to assessing students' understanding during the learning process. He states,

When we come to any sub-topic in the process [of teaching], I always have students solve exercise questions. Among them, I solve true-false, fill-in-the-blank, sequencing, multiple-choice tests, and other exercise questions. Besides that, for example, there is an application in a game style. There is a game consisting of questions related to the lesson. I access this game from a website called Fenus, where the character in the game escapes from monsters by answering questions correctly, and they can get free when they answer all the questions. Children really love such games.

These statements reflect Cenk's ability to effectively integrate ICT tools into his teaching practices for in-class formative assessment. In addition to traditional exercise questions, Cenk mentions the use of a game-like application. He describes this game as a fun way for students to engage with questions related to the lesson. Cenk accesses this game from a website called Fenus, where students can escape from monsters by answering the questions correctly, making their way through the game while retaining the knowledge. Cenk notes that children love such games, indicating the positive impact of gamified assessments on student engagement. According to these statements, Cenk's statements reflect his proficiency in utilizing ICT tools for assessment practices, incorporating various question formats and gamified assessments to gather real-time feedback on students' understanding [Assessment practices; using ICT for in-class formative assessment]. His ability to create an engaging and interactive learning environment using technology underscores his proficiency level. Thus, Cenk effectively employs ICT tools to assess students' learning progress during in-class activities, aligning with a simple adoption level of proficiency.

On the other hand, the data revealed that Cenk's proficiency level in assessment practices seem to be higher. Accordingly, he mentioned that he could utilize some online learning platforms to assign tasks and tests to his students to do at home. He illustrates this as:

For example, sometimes I send tests that need to be done in a week from EBA at the end of each unit. I know that children have homework in other lessons. An average of one week is enough for deadline, I follow up from there to see who

has done how much.

This highlights Cenk's proactive approach in using out-of-class formative assessments to gauge students' understanding and track their progress beyond the classroom environment [Assessment practices; using ICT for out-of-class formative assessment]. This implies Cenk's proficiency level in using ICT for out-of-class formative assessment exceeds simple adoption, aligning with infusive application level. His ability to effectively leverage online platforms to assign homework and monitor students' progress demonstrates a deeper integration of technology into his assessment practices, allowing for enhanced feedback and support for his students' learning needs.

In line with this, Cenk was observed in one of his classes as he assigned a task to his students (Observation of Cenk's 2nd class session). Accordingly, Cenk accessed the class page on the EBA platform and sent a screening test to all students' accounts. The task completion time was set as one week. The content included 14 questions with two pages of various question types that he had pre-loaded on his own account. He mentioned that the questions were about mass and weight. In light of this, the evidence gathered from the observation data suggests that Cenk demonstrates a high level of proficiency, specifically at the level of infusive application, in assessment practices [Assessment practices; using ICT for out-of-class formative assessment]. His utilization of online learning platforms to assign tasks and tests to students at home reflects his proactive approach in assessing their understanding and monitoring their progress beyond the traditional classroom setting.

In fact, there was another interesting evidence that indicates Cenk's ability to use ICT to leverage their scientific thinking and model construction ability. In the observed session (Observation of Cenk's 12th class session), Cenk accessed the class page on the EBA platform to open the assigned homework. A task was posted on all students' pages, which included a section for file or image uploads. He instructed the students to design a vehicle that would minimize air and/or water resistance. To begin, Cenk inquired if the students had access to a computer, smartphone, and internet. Upon learning that the entire class had access in some form, he proceeded to demonstrate how to use these devices by writing the names of the platforms where they could draw their designs on the smart board. Based on these, it is evident that Cenk effectively utilizes ICT-infused assessments to prompt students to demonstrate their scientific

thinking abilities and construct models through technology-enhanced evaluations, aligning with the rubric criteria for the level of reflective application [Assessment practices; using comprehensive ICT tools enabling product/model design]. Cenk's proficiency in this aspect of assessment practices is demonstrated at the highest level within the specified criteria.

Overall, Cenk's proficiency in assessment practices consistently aligns with the infusive application level. Moreover, Cenk effectively employs ICT tools in assessing the students during classroom teaching. However, his actions and statements reveal that Cenk is capable of conducting assessments outside the classroom. While he excels in this aspect, there is scarce evidence supporting his proficiency at higher levels within the subdimension. This scarcity of evidence for upper-level proficiency in assessment practices led to the assessment of Cenk's overall proficiency level as infusive application, as the available evidence predominantly aligns with this level.

Table 13. The proficiency levels of Cenk in assessment

Name of the Subdimension/Dimension	Proficiency Level
Understanding the students' learning needs	Simple adoption
Assessment practices	Infusive application
ASSESSMENT	Simple adoption

To sum up, Cenk's proficiency level in assessment was assessed as simple adoption level. While there were instances that pointed to a different level of proficiency in assessment practices subdimension as shown in Table 13, such as his often use of in-class formative assessments and occasional use of assigning model designing tasks to his students, Cenk demonstrated proficiency in utilizing ICT tools for out-of-class formative assessment. However, his efforts to understand students' learning needs were mostly achieved through the use of basic ICT tools, not predominantly observing students' interactions with the tools or providing self-learning opportunities through learning management systems. Thus, his overall TPACK-P proficiency in terms of assessment dimension leans towards the simple adoption level, indicating room for further development and enhancement in leveraging technology for more advanced

assessment skills in terms of both understanding students' learning needs and assessment practices.

4.1.3.2. TPACK-P Proficiency Level for Planning and Designing

Cenk's TPACK-P proficiency in planning and designing was assessed using the rubric that encompassed three subcategories. These subcategories, namely class planning the class, representations, and teaching methods, were derived through a careful examination and coding of the data. The rubric provided a structured framework for evaluating Cenk's TPACK-P proficiency in planning the class, utilizing representations, and employing teaching methods/techniques within the context of ICT integration in science education.

4.1.3.2.1. Planning the Class

In this subdimension, the data was analyzed through semi-structured interview to gain valuable insights into Cenk's proficiency in planning the class and effectively utilizing ICTs to support teaching and learning, encompassing the preparation and organization of instructional activities, setting educational goals, and aligning them with technology integration. The codes used represent the proficiency levels reflecting how effectively the teacher aligns technology with educational goals and instructional activities based on these aspects. The evidence related to these were labelled as following codes: non-ICT goal setting, using ICT to support teaching, using multiple ICTs to support learning science, and using multiple ICTs to support learning of and about science. After providing detailed examples of the teacher's practices for the available codes, it can be said that Cenk's proficiency level in terms of planning the class was assessed as infusive application level.

Based on Cenk's statements, it can be understood that he utilizes ICT to support his teaching by aligning it with the goals and content of the curriculum during planning the class. He emphasizes the importance of adhering to the program goal and pays attention to the objectives outlined in the curriculum, planning his lessons accordingly. He states,

We cannot deviate from the program goal. I pay attention to the objectives in the curriculum and the explanations given under the objectives. I am trying to plan

the lesson according to the recommendations there.

Accordingly, Cenk actively employs ICT tools to support his instruction and helps students achieve benchmark learning objectives [Planning the class; using ICT to support teaching]. This indicates a proficiency level that acknowledges his integration of technology to enhance teaching and learning but does not reach the more advanced levels of using multiple ICTs to support learning science or learning of and about science. Cenk also expresses his intention to incorporate ICT tools to enrich the learning experience. He states, *“For example, when I enter the class, I draw attention and tell a little bit. Then I try to enrich learning with ICT tools.”* This indicates that he recognizes the value of utilizing technology to enhance learning and engage students [Planning the class; using ICT to support teaching]. Consequently, his preparation and organization of instructional activities seem to aiming to support this teaching.

Furthermore, the interview data also reveals that Cenk is more proficient in terms of the aims of planning the class. For example, during the interview, Cenk shared insights into his use of multiple ICTs to support learning in the science classroom. He described his approach of attracting students’ attention at the beginning of the lesson, stating,

I either enter the lesson with an object or write a word by opening a blank page on the smart board ... we create a network...by asking the students what a concept or term I wrote ... or by writing new words around that term with examples that come to mind.

Accordingly, Cenk aimed not only to use various ICT tools to facilitate his teaching, but also to enhance students’ learning [Planning the class; using multiple ICTs to support learning science]. This shows that he could enhance the comprehension of what he wants to teach. He further explains that he enriches himself with theoretical knowledge and then structures this information using various ICT tools to facilitate learning. When asked about his lesson planning for the mass and weight subtopic, Cenk outlines his strategy, saying, *“At the beginning of this unit, we first discuss with the children their weight. Then, I state that students who think there is a mass should correct their knowledge and express their weight by multiplying by ten.”* He also mentions using videos and animations for question-and-answer sessions, providing direct theoretical information where necessary, and engaging students in solving practice questions on the smart board. These excerpts highlight Cenk’s deliberate use

of multiple ICTs, such as smart boards, videos, animations, and interactive question-and-answer sessions, to support the learning of science concepts in his classroom [Planning the class; using multiple ICTs to support learning science], suggesting infusive application level of proficiency.

Likewise, during the interview, Cenk states his considerations when selecting ICT tools to support learning in science. He emphasizes the importance of content richness and variety, stating, *“I also look at the richness of content and the variety of materials in other tools I have chosen.”* He expressed a preference for tools that provide visual explanations rather than solely relying on question tests, saying, *“I prefer the ones that are explained visually rather than the ones that have only question tests and those that have both lecture and question tests.”* Cenk highlighted the effectiveness and comprehensiveness of e-experiments conducted using ICT tools, stating, *“Of course, it is possible to set up an experiment on atoms, division, electricity, for example, but I believe that this provides a more effective and comprehensive learning in e-experiments using ICT tools.”* He also mentioned using specific platforms like EBA and Morpa, explaining that he likes the content available on these platforms and continues to use them because his students are satisfied. These statements point to how he utilizes different ICT tools to enhance students learning when organizing a science class [Planning the class; using multiple ICTs to support learning science]. Cenk’s deliberate consideration of content richness, preference for visual explanations, and the effective use of e-experiments with ICT tools all underscore his infusive application level of proficiency in integrating diverse ICT tools to enhance students’ learning experiences when organizing a science class.

Overall, in the subdimension of planning the class, Cenk’s TPACK proficiency level can be characterized as infusive application. While there is evidence in his planning that supports teaching, the overall emphasis is on supporting learning. Cenk demonstrates a proactive approach to integrating multiple ICTs and enhancing the learning experience, with an emphasis on content richness, visual explanations, and interactive e-experiments, as well as the effective use of specific platforms like EBA and Morpa. This proficiency level suggests a strong integration and application of technology to support teaching and, more importantly, learning.

4.1.3.2.2. ICT Representations

In this subdimension, the data was analyzed through classroom observations and semi-structured interview to gain valuable insights into Cenk's proficiency in utilizing ICT representation during teaching. The codes used represent the proficiency levels reflecting how effectively the teacher integrates ICT representations into his instructional practices. The evidence related to these were labelled as following codes: non-ICT representations, visualization and motivation enhancement, interactive learning support, and scientific exploration support. After providing detailed examples of the teacher's practices for the available codes, it can be said that Cenk's proficiency level in terms of ICT representation was assessed as infusive application level.

Concerning the ICT representations, Cenk seems to use them mainly for leveraging motivation and visualization. During the interview, Cenk highlighted his use of ICT representations in the classroom, emphasizing the importance of visualization and motivation. He stated, *"Well, because it adds visuality, I choose applications with abundant and varied questions. Thus, I observe that they learn better when using them because they enjoy and are more engaged."* This statement indicates Cenk's intention to utilize ICT representations to enhance visualization and motivation, recognizing their positive impact on students' learning experience [ICT representations; visualization and motivation enhancement]. This reflects not a high level of proficiency but rather it points to simple adoption level because while Cenk effectively uses ICT representations for enhancing motivation and visualization, he may not fully maximize the potential of interactive learning support or scientific exploration support as defined in the proficiency levels.

Consistent with his statements, Cenk's actions also supported his use of ICT representations were aimed to mainly provide better visualization for student learning. In the observed session (Observation of Cenk's 1st class session), Cenk opened his own page on the EBA platform and accessed the new topic to be covered. He initiated the lesson by playing an animation related to gravity and requested the students to attentively listen. The animation provided explanations about the concepts of gravitational force and its interactions. Throughout the presentation, Cenk intermittently paused and posed questions to foster student engagement and

understanding. For instance, he sought to enhance comprehension of gravity by inquiring, ‘Why do all objects in the air fall in the same direction?’ By asking such questions and presenting these ICT representations, Cenk demonstrates his effective use of ICTs to enhance students’ visualization and motivation [ICT representations; visualization and motivation enhancement], aligning with the simple adoption level of proficiency.

In similar, another observation of Cenk’s teaching involved the use of a new animation (Observation of Cenk’s 11th class session). In this animation, the movement of watercraft in water was depicted, emphasizing the concept of water resistance. One of the examples provided highlighted how the Chinese swimming team, who broke the world record in swimming in 2008, attributed their success to the full-body swimsuits they wore, made from polyurethane material, which helped reduce water resistance. In more detail, Cenk described how these swimsuits function, noting they make swift motion in water possible. Hence, the use of digital aids by Cenk displays a conscious attempt to boost the student’s mental imagery related to scientific ideas. By incorporating interactive visuals and engaging students through questions, Cenk fosters a deeper understanding and appreciation of the topic [ICT representations; visualization and motivation enhancement]. The utilization of ICT representations in this manner seems to effectively increase student visualization and promote an enriched learning experience in the science classroom. Although there are additional examples of Cenk using ICT tools to enhance visualizations and student motivation, his efforts do not indicate a high level of proficiency, as he does not actively engage students in interactive classroom activities or provide opportunities for them to explore scientific topics.

There is further evidence that Cenk’s ability to use ICT representations in order to provide interactive learning opportunities beside increasing student motivation in his classes. These were mainly observed when he presented e-experiments to his students. For example, when Cenk asked (Observation of Cenk’s 11th class session), ‘Would you like to conduct another experiment?’ the majority of the students responded eagerly with a ‘Yes.’ Then, he attempted to demonstrate changes in mass and velocity as well as the corresponding changes in kinetic energy through an e-experiment on the EBA platform. An interactive experimental environment was displayed on the screen,

featuring a setup with two different masses of balls attached to a tripod stand and a box filled with soft sand where the balls could fall into. The experiment was designed to explore how the energy of the ball, which varied due to changes in mass and height, could be altered. Cenk selected a student as a volunteer to conduct the experiment. After he had the student make the necessary observations on the screen and answer the questions, the relevant part of the experiment was completed. In this observation, it is evident that Cenk's use of ICT representations in his classes, particularly when presenting e-experiments, suggests his ability to provide interactive learning opportunities during the conceptualization of conservation of energy [ICT representations; interactive learning support]. Students' active participation and engagement in conducting experiments and answering questions further support his ability to enhance student learning through interactive ICT use, suggesting his proficiency level at the infusive application.

Cenk's statement reinforces the previous observations regarding his use of ICT representations for interactive learning. He states, *"I really love active students."* He emphasizes that he does not prefer solely verbal explanations and expects students to go beyond verbal expression. He explains, *"That's why I lift them to the board one by one, so they can touch, discuss, defend their ideas, and form arguments."* Furthermore, he believes that both successful and unsuccessful attempts should be shared on the board, stating, *"I believe that both the most successful and the least successful should stand on the board."* To facilitate this approach, he mentions opening suitable content on the smart board, indicating his intention to create an environment that supports interactive learning: *"For this, I open suitable content on the smart board."* All these statements provide further evidence of Cenk's commitment to promoting interactive learning experiences through the use of ICT representations in his classroom [ICT representations; interactive learning support], aligning with the infusive application level of proficiency.

In addition to demonstrating a higher proficiency in using ICT representations, Cenk was also observed exhibiting evidence of the highest level of proficiency. For example, when teaching the relationship between force applied and work done, Cenk demonstrated the highest level of proficiency in using ICT representations to support learning of and about science. During the observed session of his teaching

(Observation of Cenk's 3rd class session), Cenk effectively utilized multiple ICT tools to engage students in the learning process. By opening an e-experiment and presenting a question to explore the relationship between applied force and work done, he provided a hands-on and interactive learning experience. One significant observation was when Cenk invited a volunteer student to the board to respond to the question and encouraged them to test their hypothesis through observations. This approach facilitated active student participation and promoted critical thinking. Additionally, Cenk used interactive buttons and prompts on the screen, such as the + button to apply a 10N force to the robot, allowing students to directly interact with the experiment. Furthermore, Cenk's intervention to have the student access the experiment report and the subsequent discussion about the importance of multiple observations demonstrated his understanding of the research process and the need for reliable data collection. The student's consistent response and unchanged hypothesis after observing the relationship between force and work confirmed the effectiveness of Cenk's instruction in supporting students' understanding and hypothesis testing. Cenk also emphasized the significance of multiple observations by prompting the student to perform a third observation with a 30N force. The session concluded with audio and written feedback confirming the validity of the hypothesis, and Cenk reiterated the experiment to ensure thorough comprehension among the entire class. Additionally, he utilized the experiment report section to revisit the findings and explain the resulting conclusion, promoting further analysis and interpretation of the collected data.

In this observation, Cenk's proficiency in using ICT representations is directly related to supporting the learning of and about science. By utilizing the EBA platform and interactive elements, Cenk created an environment where students could actively engage with scientific concepts and principles. Through the e-experiment, students had the opportunity to explore the relationship between applied force and work done. This hands-on experience allowed them to directly observe and analyze the effects of different forces on the motion of the robot and the work performed. By manipulating variables and making observations, students were able to develop a deeper understanding of the scientific principles underlying the experiment [ICT representations; scientific exploration support]. Cenk's emphasis on multiple observations and data collection further enhanced students' learning of science. By

encouraging students to perform additional observations with different forces, Cenk demonstrated the importance of gathering reliable and diverse data to draw meaningful conclusions. This approach aligns with the scientific process and fosters critical thinking skills as students analyze their observations and refine their hypotheses. Thus, Cenk's use of multiple ICTs to facilitate interactive learning experiences, engage students in hands-on experimentation, and encourage critical thinking showcased his highest level of proficiency in utilizing ICT representations for the learning of and about science. Consequently, it is clear to claim that his proficiency level seems to be highest in terms of use of ICT representations.

Overall, Cenk's proficiency level leans primarily towards the infusive application level in ICT representations subdimension. While he demonstrates the highest level of proficiency in certain instances, the overall evidence suggests some scarcity in supporting this assessment. Additionally, there is a wealth of evidence for proficiency at lower levels. Cenk's commitment to creating interactive learning experiences aligns with infusive application, as he actively engages students in hands-on experiments and encourages critical thinking.

4.1.3.2.3. Teaching Methods/Techniques

In this subdimension, the data was analyzed through classroom observations and semi-structured interview to gain valuable insights into Cenk's proficiency in instructional strategies with varying degrees of student-centeredness when using ICTs. This subdimension assesses to teacher's preferences regarding the centeredness of teaching. The evidence related to these approaches were labelled with the following codes: completely teacher-centered, mainly teacher-centered, mainly student-centered, and completely student-centered. After providing detailed examples of the teacher's practices for the available codes, it can be said that Cenk's proficiency level in terms of teaching methods/techniques was assessed as infusive application level.

Concerning the subdimension of teaching methods/techniques, Cenk's approach to teaching methods and techniques encompasses various levels, ranging from a fully teacher-centered strategy to a partially student-centered approach. For instance, Cenk acknowledges that he predominantly employs a teacher-centered teaching approach, especially at the beginning of his lessons, where he focuses on capturing students'

attention and explaining the subject himself as he stated:

For example, when I start the lesson, I try to capture their attention and explain the subject myself to some extent. Then, I enrich their learning experiences using ICT tools. After each topic, or even subtopic, I reinforce their learning by solving questions.

Accordingly, Cenk's preference for teaching strategies are more likely to teacher-centered. This suggests a proficiency level that emphasizes a teacher-centered approach with some integration of student-involved activities but does not provide evidence for a student-centered strategy [Teaching methods/techniques; completely teacher-centered]. Thus, his proficiency level based on this instance lies upon the lack of use level.

During the observation of his teaching, several instances were observed where Cenk employed fully teacher-centered approach. For instance, when introducing the concept of conservation of energy (Observation of Cenk's 9th class session), he utilized a direct instruction method by opening an animation on the learning platform. The animation demonstrated the energy possessed by a solid object attached to a wall with a spring. In this part of his teaching, the students were observed sitting quietly, attentively watching the animation while listening to both the animation's voiceover and their teacher's explanations. In a similar way, when it came to discussing air resistance (Observation of Cenk's 10th class session), Cenk brought in an animated clip with a parachutist in it. The animation was stopped, the Pen tool was used to show the forces at work on the parachute, and direct clarifications were given to the learners. During this session, students stayed in listening mode, without much active contribution. Another case included an animated clip that portrayed how potential and kinetic energy of a ball changes as it falls from a shelf (Observation of Cenk's 11th class session). Upon pausing the clip, Cenk made clear that potential energy plus kinetic energy equals what is known as mechanical energy. These observations collectively suggest that Cenk's teaching methods during these instances leaned toward a completely teacher-centered approach [Teaching methods/techniques; completely teacher-centered], with students assuming a passive role in the learning process. In these situations, the learning environment appeared to be characterized by teacher-driven instruction, where Cenk primarily delivered content to the students. The predominant mode of engagement for the students was one of reception, as they listened and

watched the instructional materials presented by the teacher. There was no opportunity for students to actively participate, ask questions, or engage in discussions, as the teacher's explanations took center stage, ultimately suggesting his lack of use level of proficiency.

Although Cenk's teaching style primarily leans toward a teacher-centered approach, there are instances where he incorporates elements of student-centeredness, particularly by posing questions and actively seeking feedback from students. For instance, during the one of observation of his classes (Observation of Cenk's 4th class session), a new animated clip was used by Cenk to display different examples of energy such as lighting, heating, and stretching movements, and he highlighted their relation to energy effects. Cenk presented various kinds of energy, like kinetic energy, gravitational potential energy, and elastic potential energy, and also mentioned sound, electrical, and chemical energy. As the animation was coming to a close, Cenk engaged students by asking them to come up with examples of energy types and then confirmed or corrected their answers. This simple questioning strategy enabled students to actively participate in the short session of interaction with the class, contributing to a more student-centered learning environment within the predominantly teacher-centered approach [Teaching methods/techniques; mainly teacher-centered]. Thus, Cenk's level of proficiency lies at the simple adoption level based on this observation.

In another observed lesson involving a pendulum animation (Observation of Cenk's 9th class session), Cenk incorporated a series of questions to engage the students. He followed a question-and-answer format, offering clarifications and reinforcing concepts as needed. Cenk asked the students about the highest and lowest points of potential and kinetic energy in the pendulum to clarify their answers when necessary. However, it is important to note that despite these instances of student participation, the overall level of student engagement appeared to be limited, suggesting an example of mainly teacher-centered teaching since he partly used guided lecturing method [Teaching methods/techniques; mainly teacher-centered]. Cenk took the lead in presenting information, guided students through questions, and offered explanations, while the students' active involvement seemed limited in these observations.

In line with these instances, Cenk expresses himself that he tends to adapt mainly

teacher-centered strategies. He illustrates his approach as follows:

Well, usually at the beginning of a unit, at the beginning of the lesson, I either enter the lesson with an object or write a word on the board. It didn't happen in this unit, but for example, we create a network by opening a blank page on the smart board and asking the students what a concept or term I wrote with questions and answers, what it means to them, what the related concepts might be, or by writing new words around that word with examples that come to mind. While doing this and after doing it, I enrich myself with theoretical knowledge. Then I try to make them learn with various tools by structuring this information with various ICT tools.

Based on the given statements, Cenk's teaching approach reflects a mainly teacher-centered instructional style. At the beginning of the unit, he employs attention-grabbing techniques, such as presenting an object or writing a word on the board. Although not specifically mentioned in this unit, Cenk engages students in question-and-answer interactions, eliciting their understanding of the concept and encouraging them to generate connected ideas or provide relevant examples [Teaching methods/techniques; mainly teacher-centered]. This process resembles aspects of the mind-map technique, as he constructs a network of related words and enriches it with theoretical information. Additionally, Cenk utilizes various ICT tools to support students' learning and consolidation of the acquired knowledge. Thus, Cenk takes on a central role in delivering information and guiding the learning process, making it primarily teacher-centered in nature.

In essence, there are few instances pointing to Cenk's teaching strategies seem to be more student-centered. In the observed session of Cenk's teaching (Observation of Cenk's 4th class session), he opened a virtual experiment via EBA, selecting a student volunteer. The experiment showcased energy changes on various surfaces as a wooden block moved on a bowl-shaped surface. Initially, Cenk provided information through an introductory video, and the student correctly identified the comparison of potential energy, kinetic energy, and energy spent on heat. Then, he prompted the student to hypothesize about the experiment, with the student suggesting that increasing kinetic energy would decrease potential energy. Encouraging the student to test their hypothesis, an energy conversion animation confirmed their prediction. Transitioning to a low friction environment, Cenk instructed the student to observe the block's movement. Using a drawing tool, he marked where the block would reach in a

frictionless scenario and asked the class about changes in mechanical energy. When many students responded that it does not change, Cenk highlighted that mechanical energy conservation applies only to frictionless environments. Upon examination of these observation, it is evident that Cenk effectively engaged students through virtual experiments, employing questioning techniques and encouraging student participation. Visual aids such as the energy conversion animation and drawing tool enhanced comprehension and engagement. The session aligns with a higher level of proficiency, as it facilitates student comprehension and discussion of concepts while learning with ICT tools, emphasizing student-centered learning [Teaching methods/techniques; mainly student-centered]. Thus, the observation provided focuses on Cenk's effective engagement of students and their active participation in virtual experiments, demonstrating a higher level of proficiency in student-centered teaching. Nonetheless, to reach the highest level, there should be more consistent and explicit evidence of students taking the lead and participating individually or collaboratively in ICT-infused learning tasks, as well as further emphasis on inquiry-based methods throughout Cenk's teaching practices.

In line with these observations, Cenk emphasized the significance of experiential learning alongside visual and auditory stimuli, stating,

In addition to seeing and hearing, the biggest impact is through learning by doing, in my opinion. When I involve children in the lesson and when a child stands up and touches the screen, I give them both a sense of responsibility and the perception that 'I can do it,' and I find it to be very effective.

These statements highlight Cenk's approach to engaging students through hands-on activities and empowering them to take ownership of their learning. By actively involving students in the lesson and encouraging them to interact with the smart board, Cenk not only instills a sense of responsibility but also fosters a belief in their own capabilities. This approach aligns with student-centered learning and promotes active participation in the classroom. This evidence suggests that Cenk's teaching approach reaches the level of infusive application, emphasizing student-centered learning through experiential and interactive techniques. However, his statements also suggest that he continues to play the role of the conductor in the classroom, guiding and facilitating learning experiences, which may indicate the presence of teacher-led elements within these experiences suggests that it falls short of the highest level of

completely student-centered instruction.

Overall, Cenk's proficiency in terms of subdimension of teaching methods/techniques primarily aligns with the infusive application level, emphasizing a mainly teacher-centered approach. The decision to categorize him at this level is based on the comprehensive analysis of the data collected. The evidence highlights that while there are instances of completely teacher-centered instruction and some limited evidence for mainly student-centered practices, the overall pattern leans towards mainly teacher-centered strategies. This conclusion is drawn from several classroom observations where Cenk employed direct instruction methods, leading to students' passive engagement with instructional materials. His predominant role as the information provider and guide throughout the lessons suggests a teacher-centered approach. Although he occasionally incorporates student-centered elements, like posing questions and encouraging participation, these instances remain limited in comparison to his overall teaching style. This leads to the determination that his teaching methods and techniques are more aligned with mainly teacher-centered practices, ultimately supporting the assessment of infusive application as his proficiency level.

Table 14. The proficiency levels of Cenk in planning and designing

Name of the Subdimension/Dimension	Proficiency Level
Planning the class	Infusive application
ICT Representations	Infusive application
Teaching method/technique	Simple adoption
PLANNING and DESIGNING	Infusive application

To sum up, Cenk's proficiency in the planning and designing dimension aligns with the level of infusive application. This rating was justified by his demonstrated ability to employ pedagogical strategies that facilitate students' comprehension or discussion of the target concepts when learning with ICT tools. Although his teaching approach predominantly leans towards a teacher-centered style, the evidence clearly indicates that he incorporates student-centered elements through the effective use of ICT tools.

As seen from the Table 14, his proficiency level shares the common level for each subdimension and planning and designing dimension. His teaching strategies predominantly reflect a teacher-centered approach. However, he actively integrates various ICT tools to enrich content, enhance visualization, and encourage interactive learning experiences. While there are instances where his approach reaches higher levels of proficiency, the overall pattern indicates an infusion of technology into teaching, especially for content enrichment and visual aids. Cenk's planning and design emphasize the use of technology to support teaching and, more significantly, learning, placing his proficiency at the infusive application level.

4.1.3.3. TPACK-P Proficiency Level for Enactment

In this section, the observation data and interview records were analyzed to evaluate Cenk's TPACK-P proficiency in terms of ICT guiding, struggling with technical issues, and infusing ICTs into teaching contexts. The findings provided valuable insights into Cenk's competence in effectively integrating technology during instructional delivery.

4.1.3.3.1. ICT guidance

In this subdimension, the data was analyzed through classroom observations and semi-structured interview to gain valuable insights into Cenk's proficiency in guiding in utilizing ICT tools for science instruction. This subdimension focuses on the quality of ICT guidance provided by the teacher. The evidence related to this guidance were labelled with the following codes: insufficient guidance, verbal and visual instruction, learning facilitation with practice, and extensive scientific thinking and concept building. After providing detailed examples of the teacher's practices for the available codes, it can be said that Cenk's proficiency level in terms of ICT guidance was assessed as infusive application level.

With regards to ICT guidance, the interview data indicated that Cenk's proficiency in the ICT guidance subdimension appears to be at the simple adoption level. Cenk's ICT guidance is neither insufficient nor extensive on scientific thinking and concept building. As he stated, "*Children both see and learn how I draw, and [my guidance for them to understand the topics] becomes clearer and more understandable.*" Cenk

provides understandable language and visual aids to explain scientific concepts using ICT but may require further logical coherence such as a detailed step-by-step process or a clear progression of ideas in his guidance [ICT guidance; verbal and visual instruction]. These statements suggest that Cenk uses understandable language and visual demonstrations to explain the topics to students.

Parallel to this, the classroom observations reveal his active guidance and support in helping students navigate and utilize ICT tools effectively during the learning process. An example of this was observed when Cenk explained how the experiment on the relationship between potential and kinetic energy would be conducted on the smart board and expressed that the experiment would be completed in two stages (Observation of Cenk's 4th class session). He accompanied the student who conducted the experiment on the smart board, providing general instructions and asked questions to facilitate their understanding. Based on this observation, it is evident that Cenk's guidance and support in using ICT tools align with the simple adoption level, focusing on providing understandable language and visual aids to explain scientific concepts with ICTs [ICT guidance; verbal and visual instruction]. However, it should be noted that the student followed the teacher's commands rather than freely performing each action. Furthermore, this level of guidance, where the student strictly follows Cenk's instructions, may limit opportunities for the student to engage in independent practice and develop their own learning skills.

Similarly, during another observation session (Observation of Cenk's 12th class session), Cenk offered guidance to the students while explaining the task of designing a vehicle that could minimize air and/or water resistance. He provided both verbal and visual demonstrations by writing the names of the platforms on the smart board where they could execute their designs. Initially, he accessed the Tinkercad application website and guided them through the process of creating a simple design by logging in. Additionally, he introduced the 3D Modeling App, an Android application for those who preferred to complete the assignment on their phones. However, he encountered difficulties in mirroring the phone screen on the smart board, yet he made an effort to physically display the students' screens. Lastly, he opened the Paint program and demonstrated how to draw using that platform. These instances highlight that while Cenk offered explicit guidance in utilizing ICT tools, the opportunities for student

involvement in the ICT use were limited [ICT guidance; verbal and visual instruction]. Cenk's proficiency in ICT guidance is characterized by providing clear instructions and visual demonstrations to assist students in using various platforms and applications. However, there is room for improvement in terms of encouraging students to explore these tools more independently.

However, there was additional evidence suggesting that Cenk's ICT guidance could involve more student participation, which may indicate a potential for a higher proficiency level. In his own words,

I love active students. I don't enjoy only explaining things verbally, and I don't want students to express themselves solely through words. That's why I lift them up to the board one by one. I want them to touch, discuss, defend their ideas, and make arguments. I believe that both the most successful and the least successful students should have their turn at the board.

These statements underscore Cenk's strong emphasis on active student involvement, hands-on learning, and the value of physical interaction with the smart board [ICT guidance; learning facilitation with practice]. He further explains, "*For this purpose, I open suitable content on the smart board.*" These statements highlight Cenk's commitment to facilitating hands-on practice and interactive learning experiences suggests a proficiency level closer to infusive application level. Here, he employs comprehensive language and ICT tools to enhance learning and help students conceptualize scientific concepts effectively [ICT guidance; learning facilitation with practice]. It is evident that Cenk intentionally utilizes ICT tools to facilitate practice-based learning, aligning with the infusive application level in the rubric assessment.

Likewise, several instances observed in Cenk's teaching support his statements. During an observed session (Observation of Cenk's 3rd class session), he effectively used multiple ICT tools to engage students in the learning process. For example, he opened an e-experiment to explore the relationship between applied force and work done, providing a hands-on and interactive learning experience. One significant observation was when Cenk invited a student to the board and encouraged them to test their hypothesis through observations. He utilized interactive buttons and prompts on the screen, allowing students to directly interact with the experiment by applying a 10N force to the robot. Cenk's intervention to have the student access the experiment

report and discuss the importance of multiple observations demonstrated his understanding of the research process and reliable data collection. The student's consistent response and unchanged hypothesis confirmed the effectiveness of Cenk's instruction in supporting understanding and hypothesis testing. He emphasized the significance of multiple observations by prompting the student to perform a third observation with a 30N force. The session concluded with feedback confirming the validity of the hypothesis. Upon examination of these observations, it becomes apparent that Cenk effectively engage students in hands-on learning, encourage critical thinking, and provide explicit guidance for scientific inquiry. Cenk's guidance shows elements of extensive guidance on scientific thinking and concept building, while the focus on facilitating learning with practice is more prominent in the provided example. Thus, these observations are indicative of a proficiency level in line with infusive application within the rubric assessment.

Overall, within the ICT guidance subdimension, Cenk's proficiency level is assessed at infusive application. Cenk effectively utilizes ICT tools to engage students in hands-on learning experiences and encourages active participation. He provides explicit guidance and support during tasks, such as designing a vehicle or conducting e-experiments, demonstrating his ability to facilitate student understanding and construction of scientific concepts. While there are instances where his guidance may limit opportunities for independent practice, Cenk consistently emphasizes practice-based learning and promotes critical thinking among students.

4.1.3.3.2. Struggling with technical issues

In this subdimension, the data was analyzed through classroom observations and semi-structured interview to gain valuable insights into Cenk's proficiency handling technical issues during his teaching. The evidence from the interview data related to this guidance were labelled with the following codes: unable to proceed with the topic/class, inadequate technical troubleshooting and backup strategies, seeking spontaneous ICT-based solutions or delaying, and continuing the class calculatedly without interrupting. After providing detailed examples of the teacher's practices for the available codes, it can be said that Cenk's proficiency level in terms of struggling with technical issues was assessed as simple adoption level.

Regarding the aspect of struggling with technical issues, Cenk discusses his approach in dealing with such challenges during class. In his own words, he states “*Sometimes we may be left without a solution. (...) Then, we continue the lesson with the traditional method, with the textbook.*” Accordingly, he mentions that in some situations, he resorts to traditional methods and continues the class using a physical textbook. This indicates that Cenk lacks backup plans or the ability to address technical issues effectively, potentially leading to a fallback on chalk-and-talk lectures as an alternative [Struggling with technical issues; inadequate technical troubleshooting and backup strategies], where this is indication of the proficiency level of simple adoption.

Likewise, Cenk also highlights that he can overcome some simple technical problems by seeking assistance from his students and colleagues. In his own words, he states,

I ask the students. Or I ask my other teacher friends. Sometimes I do research to see what kind of solutions are available for a problem I encounter on the smart board or an application I use. I'll try them and see if they're helpful or not.

According to his statements, Cenk's proficiency can be assessed as somewhat limited. While he shows adaptability by resorting to traditional methods and utilizing physical textbooks when faced with unsolvable problems, this indicates a lack of backup plans or effective strategies for addressing technical issues [Struggling with technical issues; inadequate technical troubleshooting and backup strategies]. This aligns with the simple adoption level in the rubric's criteria, suggesting a somewhat limited proficiency in handling technical challenges during ICT-based science instruction.

However, it is worth noting that Cenk demonstrates some level of resourcefulness by seeking assistance from his students and colleagues when encountering simple technical problems. His willingness to ask for help and conduct research to find solutions is a positive aspect of his TPACK proficiency. To illustrate, it was observed in one of his classes (Observation of Cenk's 9th class session) that he encountered a technical issue with his own account password but managed to access the required online platforms using another teacher's account, demonstrating his resourcefulness and adaptability in utilizing technology effectively for instructional purposes [Struggling with technical issues; seeking spontaneous ICT-based solutions or delaying]. This suggests that Cenk handles the issue at infusive application level that does not disrupt the class or require a complete shift to traditional teaching methods.

Overall, Cenk's proficiency in handling technical issues during ICT-based science instruction aligns with the simple adoption level. He demonstrates some adaptability by seeking help from students and colleagues when facing simple technical problems, showing resourcefulness and an ability to find solutions. However, his approach indicates a lack of backup plans and effective strategies for addressing technical issues, potentially leading to fallbacks on traditional teaching methods like using physical textbooks when confronted with more challenging problems. This suggests that his proficiency level in struggling with technical issues falls within the simple adoption category. While he does show resourcefulness in seeking ad-hoc solutions, there's room for improvement in terms of consistent and comprehensive troubleshooting strategies that align with the higher levels of TPACK proficiency.

4.1.3.3.3. Infusing ICTs into teaching contexts

In this subdimension, the data was analyzed through classroom observations and semi-structured interview to gain valuable insights into Cenk's proficiency strategically integrating ICT tools into his teaching practices to enhance the overall learning environment. This subdimension focuses on a range of approaches and strategies employed by the teacher to seamlessly incorporate ICTs into instructional contexts, ultimately contributing to an enriched teaching and learning experience. The codes used reflect Cenk's proficiency levels in terms of infusing ICTs into teaching contexts, which highlight the effectiveness and depth of his integration. These proficiency levels encompass the belief that ICTs offer no contribution to teaching practices, the use of basic and convenient ICT tools for instructional enhancement, flexible and selective management of ICTs for instructional purposes, and skillful use of technology to foster student independence. After providing detailed examples of the teacher's practices for the available codes, it can be said that Cenk's proficiency level in terms of infusing ICTs into teaching contexts was assessed as infusive application level.

In terms of infusing ICTs into teaching contexts, there are different evidence pointing to Cenk was proficient at diverse levels in embedding ICT tools into class context. First, Cenk's emphasis on incorporating visual elements and interactive features into his lessons aligns with the level that focuses on basic and straightforward ICT integration. For example, his statement

Well, because it adds visuality, I choose applications that have a lot of visuality, applications that have abundant and varied questions. Thus, I observe that children learn better by using them because they enjoy and attract more attention.

suggests his focus on incorporating visual elements and interactive features into his lessons. This demonstrates his intention to strengthen his teaching by leveraging ICT tools to create a more engaging and visually appealing learning environment, which aligns with the simple adoption level [Infusing ICT into teaching contexts; enhancing teaching through basic and convenient ICT integration]. While the primary focus is on improving the teaching experience, there is also a recognition of the potential benefits for student learning. Furthermore, Cenk's proficiency level appears to be higher as indicated by his efforts in using ICTs for student learning and instructional management. In response to the question about the impact of using ICT tools on lesson performance, Cenk stated that *"It has a positive effect, making the lesson more enjoyable and increasing student participation."* This implies that he recognizes the benefits of ICT tools for enhancing the teaching environment, aligning with the simple adoption level criterion [Infusing ICT into teaching contexts; enhancing teaching through basic and convenient ICT integration]. He also noted a difference between lessons taught with and without technology by highlighting,

But if I use technology, the difference between learning levels becomes more evident. Because when I do not use ICT tools, only the most diligent students raise their hands and participate in the lesson, but if I teach with ICT tools, this situation is reflected in almost the entire class.

This underscores his acknowledgement of the potential of ICT tools to increase student engagement, further supporting his proficiency level of simple adoption [Infusing ICT into teaching contexts; enhancing teaching through basic and convenient ICT integration]. By using technology, Cenk stated that he observes a more widespread engagement among students. However, there is not clear evidence for upper-level proficiency, where the teacher skillfully handles ICT tools, using them selectively to improve student learning, or students' independent learning.

Concordantly, Cenk's statements indicated his proficiency in enhancing teaching through basic and convenient ICT integration. He stated his effective ICT tools and management of using them as

Well, because it adds visuality, I choose applications that have a lot of visuality, applications that have abundant and varied questions. Thus, I observe that children learn better by using them because they enjoy and attract more attention.

pointing to Cenk's proficiency in infusing ICTs into teaching contexts is evident. His emphasis on using ICT tools that promote visuality and offer a variety of engaging questions aligns with the benchmark of Enhancing teaching through basic and convenient ICT integration [Infusing ICT into teaching contexts]. By actively incorporating these tools into his teaching practices, Cenk not only creates a more enjoyable and attention-grabbing learning environment but also fosters increased student participation and improved learning outcomes. Thus, Cenk's effective utilization of easily accessible ICT tools to enhance classroom instruction and engage students effectively aligns with the criteria of the simple adoption level.

Additionally, one of Cenk's statement reveals his proficiency may extend beyond the simple adoption level. When responding the questions about the details of planning his ICT-based classes, Cenk emphasizes his consideration of the achievement level, number of students, demographic structure of the class. In response to how he adjusts his teaching based on these parameters, Cenk stated,

For example, I cannot solve many tests in a class where the majority of students have low success rates. The student would be bored and it would be difficult for me to get him/her to participate in the lesson because his/her interest will be low. I need to show content there so that they can understand the subject better. I can increase class participation with more modeling and experiments.

This demonstrates a more flexible and selective approach to ICT management [Infusing ICT into teaching contexts; flexible and selective management of ICTs for student learning and instructional management], where this is indicative for infusive application level. Cenk's ability to adapt his teaching strategies to the specific needs of his students reflects his proficiency in infusing ICT tools effectively for instructional purposes.

Moreover, Cenk highlighted his proficient utilization of ICT tools, demonstrating his advanced level of proficiency in incorporating technology into his teaching practices. This was evident in his meticulous planning and execution, which showcased his expertise in maximizing the benefits of ICT tools. One notable example was when he dedicated an entire class hour to discuss and evaluate students' projects (Observation

of Cenk's 12th class session), where they were tasked with designing a digital model of a vehicle optimized for minimum air and water resistance. Assigning such a task to students not only required Cenk's knowledge of relevant ICT tools but also his understanding of how to adapt them to the students' specific circumstances, such as considering the availability of computers or parents' smartphones [Infusing ICT into teaching contexts; skillful use of technology to support student independent learning]. Thus, Cenk's proficiency in skillfully utilizing ICT tools for teaching clearly aligns with the highest level of proficiency in incorporating ICTs into his teaching practices.

Likewise, during the observation of Cenk's recent class (Observation of Cenk's 15th class session), he specifically mentioned that the session would be devoted to reviewing the design assignments he had assigned the previous week and presenting them to the students. However, there were difficulties in uploading the model designs to the EBA platform. In response, Cenk reminded the students to upload three pictures of their designs taken from different angles instead. Subsequently, he checked the EBA pages of the students who had successfully submitted their assignments. It was discovered that a total of 12 students had successfully completed and submitted the assignment. Furthermore, Cenk proceeded to invite each student who had submitted their designs to present their work on the board, following the order of submission. Each student explained the type of vehicle they had designed and then elaborated on how their design was related to minimizing air and water resistance. Cenk showed appreciation and congratulated each student for their efforts. Afterward, the students returned to their seats. The designs created by the students are depicted in the Figure 14.

In this observation, Cenk stated that he would dedicate that class to reviewing the design assignments he had given the previous week and presenting them to the students. When the model designs could not be uploaded to EBA, Cenk reminded them to upload three pictures taken from different angles. Then, it checked the students who had submitted the assignment by opening their page on EBA. It seemed that 12 students had submitted the assignment. Additionally, Cenk invited the students who had made the designs sent to the board one by one in the order of the first sender. The student on the board first explained what kind of vehicle they had designed and then how this design related to air/water resistance. After he thanked and congratulated each

student, the students sat down. The students' designs were depicted in the following figure:

STUDENT	DESIGN TOOL	DESIGN PRODUCT	
STUDENT 1	Tinkercad	Land vehicle	Truck
STUDENT 2	3D Modelling	Air vehicle	Airplane
STUDENT 3	Paper Drawing	Land vehicle	Propeller Truck
STUDENT 4	Tinkercad	Water vehicle	Speedboat
STUDENT 5	3D Modelling	Land vehicle	Car
STUDENT 6	Tinkercad	Land vehicle	Train
STUDENT 7	3D Modelling	Land vehicle	Truck
STUDENT 8	Tinkercad	Land vehicle	Truck
STUDENT 9	Tinkercad	Amphibious Vehicle	Amphibious Vehicle
STUDENT 10	3D Modelling	Land vehicle	Truck
STUDENT 11	Paper Drawing	Air-Space vehicle	Rocket
STUDENT 12	3D Modelling	Land vehicle	Train

Figure 14. List of designs created by the students for the Cenk's assignment

Accordingly, Cenk's thorough checking of the students' EBA pages and the subsequent invitation of students to present their designs on the board indicates his meticulous approach to assessing student work and providing opportunities for students to showcase their learning. The students' explanations about their designs and their relation to air/water resistance highlight Cenk's ability to guide and facilitate student understanding and independent learning [Infusing ICT into teaching contexts; skillful use of technology to support student independent learning]. Cenk's expressions of appreciation and congratulations further emphasize his skillful use of technology to create a supportive and encouraging learning environment.

Overall, Cenk's proficiency level in infusing ICTs into teaching contexts is assessed at the infusive application level, primarily based on his demonstrated ability to create engaging and visually appealing lessons through the integration of interactive and visually rich ICT tools. While there is evidence suggesting proficiency at the simple adoption level, his practices also hint at a potential proficiency in reflective application. Nevertheless, the overall assessment places him at the infusive application level due to the lack of conclusive indicators for higher-level proficiency, such as skillful use or the deep reflection that characterizes reflective application. Cenk effectively enhances the teaching experience and shows consideration for potential

benefits to student learning, affirming his proficiency in incorporating ICT tools into his teaching practices at the infusive application level.

Table 15. The proficiency levels of Cenk in enactment

Name of the Subdimension/Dimension	Proficiency Level
ICT guidance	Infusive application
Struggling with technical issues	Simple adoption
Infusing ICTs into teaching contexts	Infusive application
ENACTMENT	Infusive application

To sum up, Cenk's proficiency level within the enactment dimension is assessed as infusive application. Cenk's overall proficiency level in the enactment dimension considers his proficiency in all three subdimensions, which reveal varying levels of proficiency as shown in Table 15. In ICT guidance, Cenk excels in providing explicit support and fostering hands-on learning experiences, aligning with the infusive application level by emphasizing practice-based learning and critical thinking. In the subdimension of struggling with technical issues, Cenk exhibits adaptability and resourcefulness in addressing simple technical challenges, positioning him at the simple adoption level, though his reliance on basic solutions sometimes leads to fallbacks on traditional teaching methods. Finally, in infusing ICTs into teaching contexts, Cenk effectively enhances the overall teaching experience through the integration of visually appealing and interactive ICT tools, primarily aligning with the simple adoption level, with occasional hints of reflective application. The overall assessment supports his proficiency at the infusive application level, emphasizing convenience and enhancement in his ICT integration for teaching, while also highlighting the potential for further development in achieving more transformative and comprehensive integration.

4.1.4. Case 4: Esin

In this section, a detailed analysis of Esin's TPACK-P proficiency levels in three educational dimensions was presented. Each dimension was explored to provide

insights into the proficiency of integrating technology into pedagogical practices. These dimensions included assessment, planning and designing, and enactment.

4.1.4.1. TPACK-P Proficiency Level for Assessment

Esin's proficiency level in assessment dimension was analyzed by combining data from observations of her classes and the semi-structured interview. The assessment dimension of the TPACK-P framework, which includes understanding students' learning needs and assessment practices, was used as a basis for analyzing Esin's proficiency. The collected codes were then categorized into predetermined subcategories, allowing for a comprehensive assessment of Esin's proficiency in assessment practices.

4.1.4.1.1. Understanding students' learning needs

In this subdimension, the data was analyzed through classroom observations and semi-structured interview to gain valuable insights into Esin's proficiency in using ICT tools to comprehend and address students' learning needs. This subdimension focuses on a spectrum of teacher's abilities and methodologies in utilizing ICT to assess their students' learning requirements, encompassing tasks such as the identification of misconceptions, determination of background knowledge for the topics to teach, and motivation-enhancing strategies. The codes used represent the proficiency levels reflecting how effectively the teacher assess students' learning needs based on these aspects. The evidence related to these needs were labelled as following codes; unable to use ICT effectively, using basic ICT tools, observing students' ICT interactions, and using LMS for understanding and structuring self-learning. After providing detailed examples of the teacher's practices for the available codes, it can be said that Esin's proficiency level in terms of understanding students' learning needs was assessed as infusive application level.

Regarding the understanding of students' learning needs, it was evident that Esin paid attention to how her students interacted with the ICT tools she presented to them. Her primary goal was to assess her students' reactions to those tools and monitor their learning progress. In her own words, Esin illustrated this as follows:

I make short question-answers to the students. For example, when I started the unit, I made them watch astronauts doing spacewalks and asked why they looked like they were flying. Starting from here, we moved on to the subject of mass, gravitational force. In these question-answers, I try to understand the general knowledge level of the class, what they remember from previous years, what they learned wrong by asking as many different students as possible.

According to her statements, Esin primarily utilizes basic ICT tools as probing tools for information presentation, rather than fully leveraging their potential to enhance student engagement and learning [Understanding students' learning needs; using basic ICT tools]. While she incorporates visual content, like astronauts doing spacewalks, to stimulate student thinking, her use of ICT tools seems limited to presenting information and prompting student explanations, aligning with the proficiency level of simple adoption.

Consistent with her statements, Esin was observed to use ICT tools during one of her classes (Observation of Esin's 1st class session). As she entered the classroom, she immediately started the interactive smart board, informing the students that they would be starting a new unit that day. To capture their attention and interest, she posed a question to the students, asking why astronauts appeared to be flying while performing spacewalks, while we, on the other hand, remain in contact with the ground when moving. After giving some thinking time to the students, she played an animation on the EBA platform. She reminded the students of the concept of mass, which was the topic for the fifth grade, by eliciting their answers and explanations. Based on these observations, it is evident that although Esin's approach allows her to assess the general knowledge level of the class and identify potential misconceptions, her use of basic ICT tools mainly focuses on delivering information rather than facilitating interactive and transformative learning experiences [Understanding students' learning needs; using basic ICT tools]. Additionally, her emphasis on understanding the general knowledge level, recalling previous learning, and identifying misconceptions by involving different students demonstrates her commitment to assessing students' understanding and addressing any misconceptions they may have [Understanding students' learning needs; using basic ICT tools]. Thus, these pieces of evidence align with the level of simple adoption in terms of teachers' abilities and methods of using ICT to assess their students' learning requirements.

Furthermore, through the use of ICT tools, such as animations, Esin provides students with opportunities to question and challenge their own misconceptions. In response to the question about the types of ICT tools she uses to diagnose students' misconceptions, Esin explained her strategy by stating:

A course I took while I was in graduate school was on misconceptions. In an article I read, I was interested in a study that compiled the most common misconceptions in science lessons. I still have that article on my computer. I often check that article before I start the topic of the class I teach. In this unit, for example, assuming that every moving object does work, the greater force does greater work ... I try to choose content for the children to focus on. In other words, when I come to a section about this in an animation, I stop the animation and ask questions such as 'do you think this is always the case?'. So, I always catch one or two [misconceptions] in each unit.

These statements highlight Esin's proactive approach in seeking resources and utilizing basic ICT tools to address misconceptions. Esin demonstrates proficiency in leveraging technology to enhance student learning experiences and challenge misconceptions by incorporating insights from an article on common misconceptions into her teaching practice and using ICT tools like animations [Understanding students' learning needs; using basic ICT tools]. Her deliberate efforts in selecting content and engaging students through interactive strategies support her proficiency in utilizing basic ICT tools to facilitate learning and address misconceptions. Thus, Esin's proficiency level in this instance aligns with simple adoption.

On the other hand, the interview with Esin further suggests her higher level of proficiency as she pays attention to her students' interactions with ICT tools. For example, Esin describes her strategies for diagnosing students' learning difficulties through ICT tools as follows:

Esin: Actually, it is not difficult to realize whether students understand a topic or an example. In my class, students are often rushed and excited to attend class. If they don't understand a point, I notice it from their silence, even if they don't say they don't understand. Sometimes repeating the example works, sometimes it doesn't. Let's solve a few questions first, we'll talk again, and I leave it to the solution of the question. If I still do not see as much participation and signs of learning as I would like, this time I try to find a different expression or demonstration from a new source. I do this mostly from YouTube videos. Sometimes I open animation from a different source.

Researcher: What kind of different sources do you open from?

Esin: I usually study from EBA, I use the animations and questions there a lot. However, sometimes if I think that the examples given by the students or the animation they watch are not enough, I turn on the animations in Morpa.

Apparently, Esin pays close attention to how students engage with the tools and uses their responses to understand their understanding. This allows her to adapt her teaching approach and choose suitable resources like YouTube videos or animations from platforms like Morpa. Esin's attentive approach to students' interactions with ICT tools demonstrates her proficiency in using technology to understand their learning difficulties or learning styles [Understanding students' learning needs; observing students' ICT interactions]. Consequently, Esin's proficiency level reflects infusive application, as she effectively leverages ICT tools to understand students' learning difficulties and adapt her teaching approach accordingly by closely analyzing their interactions with these resources.

In line with these statements, the observation data reveals Esin's efforts to observe her students' learning characteristics by examining their interaction with ICT tools. For example, in one of observed class of Esin (Observation of Esin's 13th class session), she utilized an interactive virtual classroom presentation consisting of images of a classroom and a teacher, previously used in online lessons. Esin emphasized this material's usefulness and mentioned their intention to make it accessible on the classroom wall in EBA for remote learners. She demonstrated the interactive features of this presentation material by reading information text and showcasing the hyperlinks embedded in images. They then transitioned to question-solving games, accessing an online matching card game through a link. The game aimed to reinforce understanding of weight and mass. Esin allowed each student at the smart board to answer three questions in a turn-based solving approach. Additionally, she incorporated music by opening a one-hour version of the song 'Boom Boom Pow' on YouTube, adjusting the volume, and engaging students in solving questions accompanied by the music. This observation data highlights Esin's effective use of ICT tools and her understanding of her students' learning preferences based on her careful observation of their interactions with these tools. Her emphasis on providing rich content and utilizing interactive tools aligns with her recognition that students learn best through watching, touching, and interacting [Understanding students' learning needs; observing students' ICT interactions]. Therefore, her proficiency in

this subdimension aligns with infusive application.

Overall, Esin's proficiency level in the subdimension of understanding students' learning needs was assessed as infusive application. While there are instances indicating a proficiency at the simple adoption level, where she primarily utilizes ICT tools for information presentation and understanding students' knowledge, her practices provide more evidence related to the infusive application level. Nevertheless, the overall assessment places her proficiency level at the infusive application level. Esin effectively enhances the teaching experience by employing ICT tools to assess students' learning needs, challenge misconceptions, and adapt her teaching strategies based on students' interactions with technology.

4.1.4.1.2. Assessment practices

In this subdimension, the data was analyzed through classroom observations and semi-structured interview to gain valuable insights into Esin's proficiency in using ICT tools for formative assessment processes. This subdimension focuses on teacher's diverse ICT-based formative assessment practices for gauging student learning, encompassing various strategies to measure and respond to students' understanding of the content being taught. The codes used represent the proficiency levels reflecting how effectively the teacher assesses students' learning during the teaching based on these aspects. The evidence related to these practices were categorized into the following codes; no use of ICT, using ICT for in-class formative assessment, using ICT for out-of-class formative assessment, and using comprehensive ICT tools enabling product/model design. After providing detailed examples of the teacher's practices for the available codes, it can be said that Esin's proficiency level in terms of understanding assessment practices was assessed as infusive application level.

Concerning assessment practices, the data obtained from the interview and classroom observations highlight Esin's assessment strategies, particularly focusing on in-class formative assessments. Throughout her classes, she incorporates numerous examples and effectively utilizes various ICT tools to assess and enhance her students' learning progress. Online platforms like EBA play a significant role in her teaching approach. To illustrate, Esin conducted a series of exercise questions on the EBA platform in one of her classes (Observation of Esin's 2nd class session), covering different aspects of

gravity, mass, and the interpretation of gravity-time graphs. The first question involved true/false statements related to gravity, mass changes on Earth and the Moon, weight-mass relationship, and the unit of mass. Students took turns answering and sitting down. In the second question, students had to match four blanks with correct answers from a set of eight options, using the drag-and-drop functionality. The following question required interpreting a gravity-time graph and selecting the correct statement about a depicted object, with students explaining their reasoning for each option. Esin made effective use of the drawing tool to annotate the chart, aiding students' interpretation and resolution of the question. These observations consistently showed Esin's proficiency in engaging students through exercise questions, providing explanations, and supporting their understanding using interactive activities on the EBA platform during the class [Assessment practices; using ICT for in-class formative assessment], aligning with the level of simple adoption in terms of her proficiency for this subdimension.

Furthermore, in another instance (Observation of Esin's 5th class session), after teaching the subtopic of physical work, Esin prompted students to reinforce their learning by solving additional practice questions on the EBA platform. In the first question, four images were presented, and students were required to identify which images demonstrated physical work (Figure 15). This activity aimed to consolidate their understanding of the concept. Later, in the following questions, three visuals were provided, and students were tasked with selecting which one depicted a scientific instance of work being done. Additionally, students were presented with a question related to a moving wheeled vehicle subject to four different forces, aimed at assessing their understanding of forces and work. Another question revolved around a scenario where a hanging mass changed its position horizontally. Students were asked to determine which force did work on the object. These observations show that Esin effectively used ICT tools and various assessment strategies to evaluate and strengthen students' understanding of the topic [Assessment practices; using ICT for in-class formative assessment]. This consistent utilization of various assessment practices and ICT tools underlines her proficiency level within the subdimension, which aligns with the level of simple adoption.

Additionally, Esin utilized different resources for in-class formative assessment

purposes other than the EBA platform.

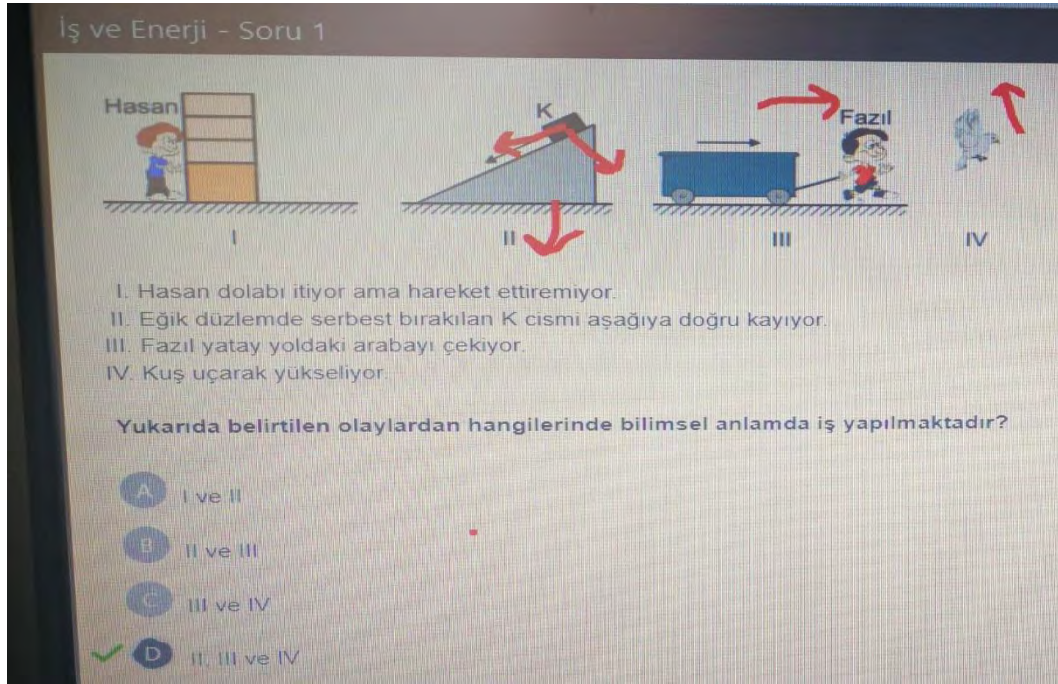


Figure 15. The image of one of the exercise questions Esin opened on the smart board

For example, it was observed in one of her classes (Observation of Esin's 2nd class session) that Esin opened the browser on the smart board and accessed the website kazanimtestleri.com to administer a comprehension test on the topic of mass and weight. The test consisted of multiple-choice questions, and students took turns standing up to solve the questions. In the first question, they were asked to match two given statements (1: quantity of matter, 2: varies with gravity) with their corresponding meanings. The options included weight-mass, weight-weight, mass-mass, and mass-weight. In another question, a picture of a balanced scale was presented, and students were asked what measurement can be made with this tool. The options included weight, mass, force, and pressure. When the next student provided the answer 'mass', Esin asked about the unit of measurement, to which the student responded with 'gram'. She confirmed that measurements are indeed made in grams or kilograms. Throughout the observation, Esin utilized an online platform to administer the comprehension test during her class, allowing students to actively participate and engage in discussions about the concepts of mass and weight [Assessment practices; using ICT for in-class formative assessment]. These findings highlight Esin's effective use of ICT tools and

external resources as formative assessment strategies to assess and support students' understanding of mass and weight concepts.

During the interview, Esin confirms that she utilizes different ICT-related sources regarding formative assessment purposes. For instance, Esin mentions that she employs various formative assessment tools such as exercise questions on the EBA platform, digital worksheets, digital leaf tests, and ready-make tests from websites like learningapps.com. However, she acknowledges not utilizing tools like Kahoot and Quiziz in the classroom due to the students' lack of tablets or laptops [Assessment practices; using ICT for in-class formative assessment]. Additionally, Esin states that she opens puzzles related to concept she taught to students. In her own words, Esin stated,

Sometimes I do puzzles. There is a site called Puzzlemaker. I identify key concepts in units where there are many concepts and create the puzzle. Then I download the puzzle and its solution separately to my flash drive and show it to the students in the lesson. Children get up and answer the puzzle one by one with the pen tool on the smart board. And when it's done, I open the answers, so we're done.

Esin's use of puzzles through a site called Puzzlemaker reflects her dedication to engaging students and reinforcing the key concepts taught in the classroom [Assessment practices; using ICT for in-class formative assessment]. The interactive nature of the puzzles, where students physically engage by answering them using the pen tool on the smart board, promotes a hands-on learning experience. This approach not only enhances students' understanding of the subject matter but also fosters their problem-solving skills and cognitive abilities, aligning with her proficiency level in this subdimension.

While Esin's assessment practices initially suggest proficiency at lower levels, a closer examination of the data reveals additional efforts and strategies that indicate a higher level of proficiency in this subdimension. During the observation, Esin was observed using the EBA platform to assign tests and materials for the whole class to complete at home (Observation of Esin's 2nd class session). After teaching the mass and weight subtopic and solving a few exercise questions on the smart board, Esin informed her students that she would be sending additional exercise questions to their EBA platform page and encouraged them to ask any questions they could not solve in the next class

[Assessment practices; using ICT for out-of-class formative assessment]. Moreover, Esin not only assigned online exercise questions but also monitored whether the students completed the tasks at home. For instance, she warned the students before sending new online exercises because only six students had completed the previous task on EBA [Assessment practices; using ICT for out-of-class formative assessment]. She emphasized that the participation in these assignments would affect their performance grading, aiming to motivate them. Based on these observations, Esin's assessment practices initially appear to align with lower proficiency levels. However, a closer examination of the data reveals her utilization of the EBA platform for assigning tests and exercises for out-of-class formative assessments. She not only assigned these exercises but also actively monitored students' completion. These instances provide strong evidence of her proficient use of the online ICT tools for out-of-class formative assessment, clearly indicating a higher level of proficiency in this subdimension.

Consistent with these, the statements from Esin's interview indicates that she is able to use EBA platform as an electronic assessment system to give students feedbacks on the tests she assigns. In her own words, Esin states,

As we finish each subtopic within the unit, I send tests to the students via EBA for them to look at home. The participation there is low, but they still provide me with feedback on their performance in different topics. For example, if they make mistakes, there is a place on the system where we can send comments, and I write to them saying, 'You made a mistake here, pay attention to these areas,' or 'You have some deficiencies in this topic, review these videos again or solve questions of this type.' Sometimes I ask students why they had difficulty solving a particular question, whether they didn't understand it or something else.

Based on these statements, it is evident that Esin demonstrates a higher proficiency level in assessment strategies. Her ability to utilize the EBA platform as an electronic assessment system for providing feedback to students on the tests she assigns aligns with the criterion of evaluating students using electronic assessment systems [Assessment practices; using ICT for out-of-class formative assessment]. Esin emphasizes her practice of sending tests to students through EBA, where they can provide feedback on their performance and receive personalized comments. This showcases her commitment to supporting students' learning and addressing any areas of improvement, indicating a stronger proficiency in utilizing electronic assessment

tools effectively, pointing to infusive application level of proficiency.

Notably, the observational data also shows Esin's proficiency seems to be at highest level. During the observation (Observation of Esin's 9th class session), it was noted that Esin informed the students about an upcoming design assignment that would be sent to their EBA pages. The assignment required students to draw a tool that considered the effects of air resistance or water resistance to facilitate daily life. Esin specified that the drawings could be created using various electronic mediums and should be uploaded as images on the EBA website. When some students mentioned their lack of access to computers, Esin suggested using smartphones as an alternative and emphasized that the assignment would be evaluated as a performance task. Furthermore, Esin also encourages those students who have no access to electronic devices at home to draw their designs on paper, take a picture, and upload it to EBA. Esin also mentioned plans to discuss the assignment in the next class and reward the best drawings. When students sought clarification on the type of tools they should design, Esin explained that they could focus on improving existing tools or even create imaginary tools that had not yet been invented. Importantly, Esin emphasized the significance of students being able to explain the purpose of their designs and their relationship to air/water resistance. Based on these observations, it is evident that Esin's proficiency in creating assessment tasks at the highest level of proficiency. This aligns with the criteria for utilizing ICT-infused assessments, showcasing Esin's proficiency in creating engaging assessment tasks that foster students' scientific thinking and model construction skills [Assessment practices; using comprehensive ICT tools enabling product/model design]. Her approach to the design assignment not only leverages technology to facilitate students' creativity but also encourages critical thinking by asking students to explain the purpose of their designs and their relationship to air/water resistance. Esin's consideration of various means for students to complete the assignment, including the use of smartphones or traditional drawings, further demonstrates her commitment to inclusive and diverse assessment practices. These observations provide strong evidence of her proficiency in developing ICT-infused assessments at the highest level.

Overall, Esin's proficiency level consistently remains at infusive application within the dimensions of assessment practices. Her assessment practices prominently feature

the effective use of in-class formative assessments through various ICT tools, demonstrating a wealth of evidence to support this level. Furthermore, there is ample evidence supporting Esin's formative assessment practices assigned to students beyond the classroom. While there are a few instances hinting at the possibility of reaching the highest level of proficiency, particularly through the integration of comprehensive ICT tools enabling product/model design, the scarcity of corroborative evidence at this level emphasizes her alignment with established practices, ultimately placing her within the infusive application proficiency level.

Table 16. The proficiency levels of Esin in assessment

Name of the Subdimension/Dimension	Proficiency Level
Understanding the students' learning needs	Infusive application
Assessment practices	Infusive application
ASSESSMENT	Infusive application

To sum up, Esin's proficiency level in the assessment dimension is consistently assessed as infusive application as shown in Table 16. In the subdimension of understanding students' learning needs, her practices exhibit a stronger alignment with infusive application, as she effectively uses ICT tools to assess students' learning needs, challenge misconceptions, and adapt her teaching strategies based on students' interactions with technology. In the subdimension of assessment practices, Esin's primary focus is on in-class formative assessments through various ICT tools, with substantial evidence supporting her proficiency level in this area, reflecting her effective use of technology to enhance in-class assessments. Furthermore, Esin utilizes the EBA platform as an electronic assessment system, assigning tests and exercises, monitoring participation, and providing personalized feedback. Her proficient use of electronic platforms suggests a solid competence at the infusive application level. While there are occasional hints suggesting the potential for reaching the highest level of proficiency, particularly through the integration of comprehensive ICT tools enabling product/model design, the limited corroborative evidence at this level emphasizes her alignment with established practices, ultimately placing her within the

infusive application proficiency level.

4.1.4.2. TPACK-P Proficiency Level for Planning and Designing

Esin's proficiency in planning and designing, as assessed within the TPACK-P framework, was evaluated across three subcategories. These subcategories were identified through a comprehensive analysis and coding of the data. Specifically, they encompassed planning the class, representations, and teaching methods.

4.1.4.2.1. Planning the Class

In this subdimension, the data was analyzed through classroom observations and semi-structured interview to gain valuable insights into Esin's proficiency in planning the class and effectively utilizing ICTs to support teaching and learning, encompassing the preparation and organization of instructional activities, setting educational goals, and aligning them with technology integration. The codes used represent the proficiency levels reflecting how effectively the teacher aligns technology with educational goals and instructional activities based on these aspects. The evidence related to these were labelled as following codes: non-ICT goal setting, using ICT to support teaching, using multiple ICTs to support learning science, and using multiple ICTs to support learning of and about science. After providing detailed examples of the teacher's practices for the available codes, it can be said that Esin's proficiency level in terms of planning the class was assessed as reflective application level.

In terms of planning the class, mainly interview data provides valuable insight of Esin's proficiency level. During the interview, Esin mentions, *"For example, my first plan is to determine the question or example for the lesson introduction. Then, I decide how to transition to the next topic, in what order to show animations."* These statements from Esin's interview demonstrate her ability to arrange ICTs to support her instruction. She expresses her consideration of using ICT tools, such as animations, in a strategic manner to facilitate the delivery of her lessons. This evidence indicates that Esin's proficiency aligns with the criteria of arranging ICTs to support teacher's instruction and helping students achieve benchmark learning goals [Planning the class; using ICT to support teaching]. Thus, this instance shows that Esin primarily focus on her planning purpose is related to enhancing her teaching.

On the other hand, Esin's further statements in the interview portray a higher proficiency level of herself in terms of planning the class aspect. Esin stated that she aims to present different ICT tools to her students to satisfy their learning needs as follows:

Whether it's the practice questions in the EBA or the questions I open from other sources, I try to have students solve all these in turn, trying to both meet their needs and see different content. For example, they love the experiments and games we do on the smart board.

Accordingly, Esin emphasizes the importance of utilizing various ICT tools to cater to her students' learning needs and engage them through interactive activities like experiments and games on the smart board [Planning the class; using multiple ICTs to support learning science]. Her proficiency in using multiple ICTs to support learning science reflects her dedication to enhancing students' conceptual comprehension and addressing misconceptions effectively.

Moreover, Esin explains that she incorporates various ICT tools in her classes to enhance the learning experience for her students. She mentions using platforms like EBA and occasionally Morpa, as well as utilizing specific resources such as Phet simulations for physics activities. She also utilizes classic technologies like Microsoft Office programs (Word and PowerPoint), Google Docs and Slides, and occasionally connects her phone to the smart board. Additionally, she mentions using applications like Beaker for demonstrating chemical reactions visually and engaging students with gas releases or color changes. Another application she uses is 'Kimya Kim Yaa,' which involves answering questions and playing games to reinforce knowledge of the periodic table. These ICT tools provide interactive and engaging learning opportunities for her students [Planning the class; using multiple ICTs to support learning science]. Esin also highlighted the importance of student sociability and her efforts to activate students through various means, such as standing up at the blackboard or expressing opinions freely. She mentioned, *"Sometimes it is not easy for them to do this directly, but they are more comfortable when they touch the screen on the smart board or want to open and show something. I try to increase those moments."* These statements demonstrate Esin's commitment to fostering student engagement, promoting interactive experiences, and leveraging technology tools to enhance learning opportunities [Planning the class; using multiple ICTs to support learning science].

Thus, Esin's adept use of a wide array of ICT tools underlines her proficiency in creating diverse and dynamic learning experiences that promote student engagement and understanding of scientific concepts, further supporting her infusive application level of proficiency.

Furthermore, several of Esin's statements provide evidence of her higher proficiency level. When asked about her primary expectations from students in ICT-infused classes, Esin emphasized her goal of nurturing science literate individuals by incorporating technology into her teaching practices. During the interview, Esin provided evidence supporting her proficiency in planning ICT-infused classes and designing tasks that encourage students' scientific explorations and concept construction. She expressed her expectation for students to possess basic subject knowledge, aiming to develop science literacy by associating lessons with daily life situations. Esin stated, *"I expect them to have basic knowledge of the subjects they need to learn in order to succeed in being a science literate individual. We associate our lessons with daily life as much as we can."* This illustrates her intention to create awareness about real-life problems and involve students in finding solutions. For instance, she stated that she assigned a design project where students researched and made scientific arguments to improve a tool used in daily life to reduce air and water resistance, emphasizing their ability to communicate through drawing [Planning the class; using multiple ICTs to support learning of and about science]. Consistent with these, Esin's other statements affirms her emphasis on nurturing on science literate students as follows:

... It's not just knowledge [I want them to have]. [I want the students to] stand up on the smart board and do experiment there, change the variables, develop, and test hypotheses. In other words, I want them to acquire scientific process skills as well.

These statements indicate that Esin holds a strong emphasis on developing science literate students by focusing on more than just knowledge. She expresses her desire for students to actively participate in the learning process by standing up on the smart board, conducting experiments, and engaging in activities that involve changing variables, developing hypotheses, and testing them. This highlights Esin's goal of fostering scientific process skills, which go beyond mere content knowledge and involve critical thinking, problem-solving, and hands-on exploration. Thus, Esin's

commitment to nurturing science literate individuals through technology-infused teaching is reflected in her ability to design tasks that encourage students' scientific explorations, construct scientific concepts, and apply their knowledge to real-life scenarios [Planning the class; using multiple ICTs to support learning of and about science], further demonstrating her proficiency at the reflective application level in the planning of ICT-infused classes.

During observations of Esin's teaching, it is evident that she successfully implemented what she mentioned in the interview. As an example, a design task was assigned by Esin to her students, requiring them to create a vehicle that minimizes resistance (Observation of Esin's 9th class session). This task was intended for completion at home, and Esin encouraged the use of various ICT tools to accomplish it. Thus, Esin effectively implemented her teaching approach by incorporating ICT tools into a design task that encouraged students to explore scientific concepts [Planning the class; using multiple ICTs to support learning of and about science]. While the observation did not provide insights into the classroom evaluation process, it underscores Esin's practical application of ICT tools in creating tasks that align with the reflective application level, fostering students' scientific exploration and critical thinking skills.

Overall, in the subdimension of planning the class, Esin's TPACK proficiency level can be characterized as reflective application. This level involves the use of multiple ICTs to support learning in and about science. Despite instances indicating lower proficiency levels, Esin consistently demonstrated her ability to design a curriculum infused with technology, which engaged students in scientific explorations, concept development, and problem-solving activities. Through the integration of technology, she provided ample opportunities for students to deepen their understanding of scientific concepts and cultivate crucial scientific process skills. Esin's dedication to incorporating ICT tools and fostering student engagement exemplifies her commitment to enhancing science education through innovative teaching strategies, thus justifying the assessment at the reflective application level.

4.1.4.2.2. ICT Representations

In this subdimension, the data was analyzed through classroom observations and semi-structured interview to gain valuable insights into Esin's proficiency in utilizing ICT

representation during teaching. The codes used represent the proficiency levels reflecting how effectively the teacher integrates ICT representations into his instructional practices. The evidence related to these were labelled as following codes: non-ICT representations, visualization and motivation enhancement, interactive learning support, and scientific exploration support. After providing detailed examples of the teacher's practices for the available codes, it can be said that Esin's proficiency level in terms of ICT representation was assessed as infusive application level.

Regarding the use of ICT representations, Esin was observed in the classroom when utilizing various ICT representations for purposes of enhancing motivation and visualizations. To do this, she utilized mainly animations on the smart board. During displaying these animations, Esin was mainly playing active role while students rarely attended to class. During the observation of one of Esin's teaching (Observation of Esin's 1st class session), it was noted that a dialogue and observation concerning mass and weight was initiated with the students. She utilized an animated clip to highlight the distinctions between mass and weight. The clip explained the units of measurement, the tools involved, and how these measurements can vary based on location and gravitational effects. Through this visual representation, students gained a clearer understanding of the concepts and how they are measured in different environments. The use of digital visuals enhanced students' comprehension of mass and weight, enabling them to differentiate between the two and grasp their confusions. The animated clip served as a valuable visual aid, facilitating a deeper understanding of the topic [ICT representations; visualization and motivation enhancement]. This observation aligns with Esin's proficiency level, which is assessed as simple adoption within the ICT representations subdimension.

On the other hand, there is a substantial amount of evidence that indicates Esin's proficiency level extend beyond the simple adoption level. For example, in one of Esin's classes (Observation of Esin's 7th class session), she introduced a new animation to the students on the smart board, initiating a mini discussion about the factors influencing the motion of a train on a roller coaster. By prompting the students to consider the role of frictional force, Esin guided their thinking towards a specific concept. The animation was then played, illustrating the conversion of mechanical energy into heat energy and presenting real-life examples and historical references

related to perpetual motion machines. This effectively showcased the concept of non-conservation of mechanical energy due to the formation of heat energy through friction. Esin encouraged student engagement by asking them to provide additional examples of situations where heat energy is generated [ICT representations; interactive learning support]. This aligns with the criteria for the infusive application level.

In addition to animations, Esin employed various digital displays such as drawings to create interactive learning opportunities for her students. During a class on gravitational potential energy (Observation of Esin's 5th class session), Esin drew a tree on the smart board and added two apple shapes on different branches. This drawing sparked a discussion about the factors influencing gravitational potential energy. When Esin asked which apple had the greatest potential energy, the class offered diverse responses. To address these different viewpoints, two more apples were drawn on the same branch, one smaller and one larger, prompting students to compare them. This visual representation conveyed the idea that both mass and height play crucial roles in determining gravitational potential energy. She emphasized that mass contributes to the magnitude of potential energy, while height affects its value. Furthermore, Esin highlighted that the apple on the higher branch possessed higher gravitational potential energy compared to the one on the lower branch. In the second drawing, she underscored that a larger apple, due to its greater mass, would possess more gravitational potential energy. Based on these observations, Esin's successful implementation of interactive learning opportunities through visual aids [ICT representations; interactive learning support], not only enhances students' understanding of complex scientific concepts but also encourages active engagement with the material, ultimately suggesting her infusive application level of proficiency.

Esin's statements also serve as evidence of her proficiency in integrating ICT-infused representations and tools to engage students in interactive learning experiences. She emphasizes the importance of student engagement and activation, stating, *"Sometimes it is not easy for them to do this directly, but they are more comfortable when they touch the screen on the smart board or want to open and show something."* This highlights her efforts to create opportunities for students to interact with ICT tools [ICT representations; interactive learning support]. Furthermore, Esin assigns learning tasks that encourage students to develop scientific process skills, as she mentions, *"I*

wanted them to develop their ability to communicate through drawing.” This demonstrates her intention to foster students’ conceptualization of science concepts and scientific thinking [ICT representations; interactive learning support]. These statements indicate her proficiency at the infusive application level, where she actively integrates ICT tools to facilitate interactive learning experiences.

Esin’s efforts and statements also indicates that she utilizes ICT representations to support student interactive learning. In her own words,

... It’s not just knowledge [I want them to have]. [I want the students to] stand up on the smart board and do experiment there, change the variables, develop, and test hypotheses. In other words, I want them to acquire scientific process skills as well.

These statements highlight Esin’s desire to see active students in her class while they learn. Upon the question of what kind of ICT representations, she used in class to achieve this, she replied that “*Animations, simulations, interactive experiments, exercise questions in EBA... Apart from that, Phet simulations, YouTube, E-puzzles and so on*” Although animations and videos were observed to be hardly useful for creating interactive environment for student learning, e-experiments, simulations, and puzzle solving are more suitable to active participation of students to use or interact with ICT representations [ICT representations; interactive learning support]. This approach aligns with the proficiency level of infusive application within the ICT representations subdimension.

Likewise, the observation data presented evidence for her use of ICT representations at higher proficiency. Based on the observation data (Observation of Esin’s 1st class session), Esin initiated an activity where students explore the concept of weight on different planets using an interactive display on the smart board screen. The students are actively engaged in the process as they enter their mass, and the system calculates their weight on Earth. Interactive drawings help students understand how mass, weight, and gravity work together. In order to think about how their weight might change on planets of different sizes like Mars and Saturn, Esin asked a question to students. Students were active participants in their learning via the use of digital tools such as interactive simulations, which increased their understanding of the subject. She facilitated conversations and pushed students to examine and explain the results, which

enhanced their comprehension. Esin also utilized these digital tools to discuss how the density of solid and gas planets differs and how this influences gravity. In these observations, Esin supported student involvement, helped them visualize, and promoted understanding of the concepts of weight, mass, and gravity on different planets by using these digital tools, including interactive simulations and drawings [ICT representations; interactive learning support]. Thus, Esin's adept utilization of digital tools and interactive simulations reflects her proficiency at the infusive application level, emphasizing her ability to actively engage students in exploring and comprehending scientific concepts.

Similarly, in another class of Esin (Observation of Esin's 7th class session), she opened an interactive simulation featuring a roller coaster on the screen. The students were tasked with determining the highest and lowest points of speed for the train. Esin explained that they would use a voting method instead of allowing volunteers. They created columns labeled A, B, and C on the unused side of the smart board and asked students to indicate their choices. After starting the simulation, she asked if anyone had changed their mind. Some students revised their answers, and the responses were checked. Then, she asked the class why the speed was highest at a certain point. Several students raised their hands. One student suggested that the answer was the last point because of its position, prompting her to ask if such a generalization could be made. Another student disagreed, arguing that the fastest point would be the deepest. Another student added that neither generalization could be made since descents increased speed while ascents decreased it, suggesting that the point with the most descent should be considered. Esin praised the students for expressing their ideas and acknowledged that the last response was the most accurate. She explained, 'Let's not forget that the presence of potential energy initiates the formation of kinetic energy. As you observed from the speed indicator, there is a lower speed at the first two points where some of the potential energy cannot convert to kinetic energy. However, at point C, almost all the potential energy has transformed into kinetic energy, generating more kinetic energy compared to point B.' Esin also mentioned that the simulation assumed a frictionless environment and highlighted that they would learn about the changes that would occur with friction. Upon examination of these observations, through the incorporation of interactive simulations and engaging discussions, Esin's

implementation of ICT representations fosters an environment of interactive learning [ICT representations; interactive learning support]. In these examples, Esin's approach encourages students to discuss and understand scientific concepts actively but does not involve extensive virtual experiments, in-depth exploration of scientific phenomena, or the development of comprehensive science process skills that characterize the highest level, scientific exploration support. Instead, these instance showcase Esin's infusive application level of proficiency where her students actively engage with ICT representations to enhance their conceptual understanding.

Esin's use of ICT-infused representations was observed at the highest level in only one instance. At the end of the unit (Observation of Esin's 14th class session), Esin opened a presentation file in PDF format, which had been used for distance education in the past. Notably, the file contained interactive elements such as images and clickable links. Esin mentioned her intention to make the file available on the EBA platform, providing students the opportunity to access it from home. By reading a portion of the information text and showcasing the links that opened related content, such as books, balls, and cars, Esin engaged students in an interactive learning experience. Transitioning to question-solving games, Esin tapped a link labeled 'boom' on the screen, leading to an online matching card game hosted on learningapps.org. The instructions prompted students to drag the provided information onto either the weight or mass side. Esin facilitated the activity by allowing students to take turns at the blackboard, providing each student with the chance to answer three questions. To enhance the learning environment, she played a one-hour version of the song 'Boom Boom Pow' on YouTube, adjusting the volume to accompany students' engagement with the questions. Through these observations, it is evident that Esin effectively integrated ICT-infused representations, such as interactive presentations and online games, to foster student participation and understanding. The incorporation of technology and interactive elements showcased Esin's proficiency in utilizing ICT tools to support scientific exploration and engage students in a dynamic learning process [ICT representations; scientific exploration support], implying her advanced proficiency in utilizing ICT tools for enhanced science education.

Overall, Esin's proficiency in utilizing ICT representations falls within the infusive application level, primarily focusing on interactive learning support. This is evident

from her use of animations, interactive simulations, and visual aids to enhance students' understanding of complex scientific concepts while encouraging active engagement. However, she also demonstrates elements of simple adoption and reflective application in some instances, suggesting that her proficiency varies across the spectrum of ICT integration. Yet, her overall proficiency lies at the infusive application level, indicating her ability to effectively incorporate technology into science education, particularly through interactive and visual learning support.

4.1.4.2.3. Teaching Methods/Techniques

In this subdimension, the data was analyzed through classroom observations and semi-structured interview to gain valuable insights into Esin's proficiency in instructional strategies with varying degrees of student-centeredness when using ICTs. This subdimension assesses to teacher's preferences regarding the centeredness of teaching. The evidence related to these approaches were labelled with the following codes: completely teacher-centered, mainly teacher-centered, mainly student-centered, and completely student-centered. After providing detailed examples of the teacher's practices for the available codes, it can be said that Esin's proficiency level in terms of teaching methods/techniques was assessed as simple adoption level.

To gain insight into Esin's proficiency level in teaching methods/techniques, both interviews and classroom observations data were examined. These methods indicate the extent to which Esin employed teacher-centered and student-centered strategies in her teaching approach. For example, in one of her classes (Observation of Esin's 7th class session), Esin utilized an animation to illustrate the concept of the conservation of mechanical energy. The animation demonstrated the relationship between potential and kinetic energies and emphasized the conservation of mechanical energy. Esin tried to enhance the students' understanding by pausing the animation at certain points and reinforcing the explanation with questions. Meanwhile, student rarely participated to the class only when responding their teacher's questions [Teaching methods/techniques; mainly teacher-centered]. This shows that Esin's teaching methods seem to be leaning towards a more teacher-centered approach.

Likewise, when teaching energy transformation (Observation of Esin's 8th class session), Esin asked the students to identify the type of energy present in a falling apple

on a tree and encouraged them to think about the energy transformation. This interactive approach facilitated student engagement and comprehension of the topic. Furthermore, the animation showcased the change in potential energy and the corresponding increase in kinetic energy as the object fell. Esin verbally guided the students by providing examples and prompting them to think about other instances where potential energy is converted into kinetic energy. This observation indicates that Esin holds teacher-centered way of teaching while she includes her students to the class occasionally [Teaching methods/techniques; mainly teacher-centered]. Thus, since the use of the animation and questioning techniques contributed to mainly teacher-centered teaching experience, her proficiency level remains at simple adoption level.

Similarly, Esin was observed in another her class to use a simulation to illustrate how energy changes in such systems, accompanied by a graphical representation showing potential, kinetic, and heat energies (Observation of Esin's 8th class session). When starting the simulation, it was noticed that the object's maximum potential energy decreased to zero at the bottom of the pit, while its kinetic energy became the sole contributor to its total energy. Esin engaged the students by asking them to predict the expected changes and provided a corresponding option on the screen. The students correctly identified the decrease in mechanical energy due to energy conversion into heat caused by friction. Additionally, Esin visually emphasized the concepts by enclosing the labels for kinetic and potential energies within a box, signifying their categorization as mechanical energy. These observations suggest that she employed pedagogical strategies that fostered students' understanding and motivation in comprehending energy transformations in systems with friction. However, the approach predominantly relied on mainly teacher-centered methods, as the students were actively responding to the teacher's questions but not initiating their own inquiries [Teaching methods/techniques; mainly teacher-centered], reflecting that her level remains at simple adoption as she primarily employs teacher-centered methods.

On the other hand, the classroom observations also revealed that Esin's teaching in ICT-infused classes tends to be more student-centered. During one of her classes (Observation of Esin's 7th class session), Esin utilized an interactive experiment on the EBA platform to investigate the relationship between applied force and work. The

students actively participated in the experiment, formulating hypotheses, and engaging in data collection and observation. Esin guided the students through questioning and verification of their understanding. They observed that as the applied force increased, the work performed by the object also increased. This supported their hypothesis of a direct relationship between force and work. Esin encouraged further observations and discussions, allowing students to explore different force values and their corresponding work outcomes. The students analyzed the experiment data and confirmed that it aligned with their initial hypothesis. Her emphasis on the importance of variables and their representation in the experiment report further facilitated students' understanding. Based on these observations, Esin engaged her students in an interactive experiment, encouraged them to formulate hypotheses, actively participate in data collection and observation, and engage in discussions to explore and verify their understanding. This demonstrates an approach that shifts the focus toward students' comprehension and discussions of the target concepts during ICT-assisted learning, encouraging their active involvement and participation in the learning process [Teaching methods/techniques; mainly student-centered]. While the students are actively engaged and participate in the experiment, it may not be considered completely student-centered since there is still some guidance and questioning provided by Esin, suggesting elements of teacher involvement. These practices demonstrate her proficiency in embracing pedagogical strategies that facilitate students' comprehension and discussion of the target concepts when learning with ICTs, indicating an infusive application level of proficiency.

Concordantly, in another class (Observation of Esin's 7th class session), Esin employed an interactive simulation to explore speed variations on a roller coaster. Rather than allowing volunteers, Esin chose to gather responses through a voting method. She set up columns labeled A, B, and C on the unused side of the smart board and asked the students to indicate their choices for the highest and lowest points of speed. The students were asked to indicate their choices for the highest and lowest points of speed. The simulation was started, and Esin inquired if anyone had changed their mind. Some students revised their answers, and the responses were checked. Then, Esin prompted the class to explain why the speed was highest at a specific point. Different opinions were shared among the students, with one suggesting the last point, another suggesting

the lowest point, and another arguing for considering the most significant descent. Esin praised the students for their contributions but clarified that the correct answer was the last response. She further explained the relationship between potential and kinetic energies, highlighting how the conversion of potential energy into kinetic energy resulted in different speeds at different points. Esin also mentioned that the simulation assumed a frictionless environment and informed the students that they would explore the changes that would occur with friction. In the second part of the interactive activity, she opened an informative simulation to enhance the students' understanding. According to these observations, Esin employed an interactive simulation, allowed students to actively participate by voting and providing their opinions, and engaged in discussions regarding the subject matter. This approach fosters active involvement, participation, and student comprehension, aligning with the characteristics of mainly student-centered teaching methods [Teaching methods/techniques; mainly student-centered]. These practices demonstrate her proficiency in utilizing pedagogical strategies that facilitate students' comprehension and discussion of the target concepts when learning with ICTs, supporting infusive application proficiency level.

In accordance with these observations, Esin's statements support her tendency to adopt more student-centered teaching strategies. During her interview, Esin emphasized her commitment to student-centered teaching, saying,

Well, we teach the lessons as student-centered as possible. I am trying to get the student to talk and to act. Questioning is a method I use often. Apart from that, I use visual elements such as video, animation, simulation. Sometimes we do virtual experiments.

This statement reinforces her inclination toward a student-centered approach in her classes, aligning with the observed teaching methods that encourage active student involvement, participation, and comprehension [Teaching methods/techniques; mainly student-centered], confirming her proficiency level falls within infusive application.

Only in one instance, Esin was observed to be completely student-centered. When assigning the design task to students, she informed the students about an upcoming design assignment that would be sent to their EBA pages. The assignment required students to draw a tool that considered the effects of air resistance or water resistance

to facilitate daily life. Esin specified that the drawings could be created using various electronic mediums and should be uploaded as images on the EBA website. When some students mentioned their lack of access to computers, Esin suggested using smartphones as an alternative and emphasized that the assignment would be evaluated as a performance task. In this observation, it appears that Esin's teaching method indeed aligns more with the reflective application level [Teaching methods/techniques; completely student-centered]. he not only gives students the flexibility to choose the medium for their design task but also encourages them to design vehicles that can improve existing ones or even invent new imaginary vehicles. This approach places students at the forefront of the creative process and emphasizes their ability to think critically and articulate the reasoning behind their designs, which is indicative of a completely student-centered approach.

Table 17. The proficiency levels of Esin in planning and designing

Name of the Subdimension/Dimension	Proficiency Level
Planning the class	Reflective application
ICT Representations	Infusive application
Teaching method/technique	Infusive application
PLANNING and DESIGNING	Infusive application

Overall, Esin's teaching methods and techniques tend to lean more towards mainly student-centered strategies, with limited instances of teacher-centered approaches. Her general approach is primarily student-centered, where students often engage actively with the learning process. However, there was one notable exception when Esin assigned a design task to his where she employed a completely student-centered teaching method, reaching the highest proficiency level in this subdimension. Nonetheless, her overall inclination aligns more with the mainly student-centered category, emphasizing her proficiency in creating an interactive and engaging learning environment for her students. Therefore, Esin's proficiency level in teaching methods and techniques was assessed as infusive application, given her overall preference for mainly student-centered approach.

To sum up, Esin's proficiency level in planning and designing falls within the infusive application level. As indicated in Table 17, Esin reaches to highest proficiency level in the planning the class subdimension, showcasing her consistent integration of technology into curriculum design, which actively engages students in scientific exploration and concept development. This demonstrates the highest level of proficiency. However, in the subdimension related to utilizing ICT representations, Esin remains at the infusive application level, with a focus on interactive learning support rather than support for scientific exploration. When it comes to her teaching methods and techniques, her overall approach tends to lean more towards the mainly student-centered category. Considering the evidence across these subdimensions, Esin's proficiency level in the planning and designing dimension is accurately assessed as falling within the infusive application level.

4.1.4.3. TPACK-P Proficiency Level for Enactment

In this section, the data from classroom observations and interviews were analyzed to examine Esin's proficiency in the practice of TPACK-P. Specifically, the focus was on ICT guiding, struggling with technical issues, and infusing ICTs into teaching contexts under the title of enactment.

4.1.4.3.1. ICT guidance

In this subdimension, the data was analyzed through classroom observations and semi-structured interview to gain valuable insights into Esin's proficiency in guiding in utilizing ICT tools for science instruction. This subdimension focuses on the quality of ICT guidance provided by the teacher. The evidence related to this guidance were labelled with the following codes; insufficient guidance, verbal and visual instruction, learning facilitation with practice, and extensive scientific thinking and concept building. After providing detailed examples of the teacher's practices for the available codes, it can be said that Esin's proficiency level in terms of ICT guidance was assessed as infusive application level.

Regarding ICT guidance, Esin effectively incorporated a range of ICT tools in her classes to facilitate students' attainment of learning objectives. She illustrates this in the interview as follows:

In virtual classroom presentations, I sometimes use my virtual classroom presentations. I had used it in this unit as well. I had prepared it in Google Slides initially, then converted it to PDF, which I now carry in my memory. Here, I aimed to enable students to open their computers or phones and learn somewhat independently by reading the instructions. This term, at the end of the unit, I showed students how to use it so that someone might want to redo it. Unfortunately, I couldn't do it myself because I fell behind on my schedule.

This statement aligns with the level of verbal and visual instruction in terms of ICT guidance subdimension's criteria. Esin emphasizes her use of ICT tools and materials for instructional purposes, particularly Google Slides and PDFs, which she expects students to utilize for self-directed learning based on provided instructions. However, it does not reflect the level of learning facilitation with practice or level of extensive scientific thinking and concept building as she primarily relies on the materials to convey information rather than offering extensive verbal explanations or in-depth support for scientific concept development [ICT guidance; verbal and visual instruction]. Thus, her level is more likely situated at the level of simple adoption.

In line with this, during the observation of her teaching when she assigned the design task to students (Observation of Esin's 9th class session), it is evident that Esin's guidance remains limited. In this class, Esin introduced the task to students, and briefly mentioned the names of some ICT tools that students could use for their designs. However, explicit instruction or detailed guidance on how to effectively utilize these tools was not provided by her. Therefore, this guidance primarily served to inform students about the tools that can be used during designing their vehicles [ICT guidance; verbal and visual instruction]. Thus, Esin's level in this subdimension appears to align more with the level of simple adoption.

In addition to the aforementioned examples, there are instances where Esin provides greater guidance to her students. For instance, in one class (Observation of Esin's 13th class session), Esin introduced a virtual classroom presentation that had been previously used for online education. She explained that this document would be uploaded to the class wall on the EBA platform, providing a valuable resource for students interested in at-home study. During this demonstration, Esin not only read sections of the informative text but also actively engaged students in exploring the interactive links associated with visuals like books, balls, and cars. This observation suggests that Esin's level aligns with the learning facilitation with practice category.

She effectively utilizes ICTs to offer students supplementary resources, promotes interactive learning experiences, and facilitates the conceptualization of scientific concepts [ICT guidance; learning facilitation with practice]. While the observation does not explicitly reveal comprehensive guidance, it does indicate a level of infusive application.

Similarly, in her another class (Observation of Esin's 11th class session), Esin presented a question with a complex graph that did not fit entirely on the screen. The student who went to the smart board was instructed by Esin to zoom in on the question and graph to ensure clarity. The question involved determining the corresponding column graph representation of the potential energies at different points indicated on the given line graph. When the student hesitated, Esin asked for their understanding of the answer choices. The student interpreted it as 'being represented by a high level of energy.' She confirmed this interpretation and encouraged the student to think about the relationship between speed and kinetic energy. When asked how the kinetic energy changes when the speed increases, the student responded with 'it increases.' Then she explained how potential energy converts to kinetic energy in a frictionless environment, and guided the student in representing these changes on the graph. The student successfully demonstrated their understanding by labeling the graph with PE and KE symbols and using directional arrows to indicate the rise and fall of energy. They also expressed the relationships between kinetic and potential energies at each point. Esin praised the student for finding the correct answer. In this example, Esin effectively used understandable language to explain the target scientific concepts related to energy transformations with the help of the graph [ICT guidance; learning facilitation with practice]. She facilitated the student's understanding through interactive engagement and questioning. Her guidance allowed the student to practice applying their knowledge and conceptualize the relationship between potential and kinetic energies.

Likewise, in another class of Esin (Observation of Esin's 12th class session), it was observed that a student paused to think upon reading the question. Then, she prompted the student to recall the conditions necessary for work and asked them to state it. The student responded by mentioning that work requires movement and force in the same direction. However, when she inquired about the exact definition of weightlifting, the

student seemed uncertain. In response, Esin guided the student to use the internet browser to search for images of weightlifting. Following her instructions, the student conducted a search on the internet browser. Subsequently, the student expressed their understanding by stating that work only occurs when lifting weights, whereas in other situations without movement, there is no work. This observation provides clear evidence of her proficiency in ICT guidance. Esin effectively guided the student in using ICT tools, specifically the internet browser, to gather information and clarify their understanding. By encouraging the student to search for images related to weightlifting, Esin facilitated the student's recall of the concept. This demonstrates her ability to utilize ICTs as a resource for information retrieval and knowledge construction [ICT guidance; learning facilitation with practice]. The guidance provided by Esin enabled the student to make connections between the concepts of work and weightlifting. Thus, these observations indicate that Esin's proficiency level in ICT guidance is at the infusive application level.

Overall, within the ICT guidance subdimension, Esin's proficiency level was assessed at infusive application. She demonstrates a range of ICT guidance practices, from providing basic verbal and visual instruction to facilitating learning with practice and enabling students to make connections between concepts. While there are instances where her guidance is more limited, indicating simple adoption level, the overall pattern suggests a tendency towards more comprehensive guidance in utilizing ICTs for learning purposes, emphasizing the infusive application level.

4.1.4.3.2. Struggling with technical issues

In this subdimension, the data was analyzed through semi-structured interview to gain valuable insights into Esin's proficiency handling technical issues during his teaching. The evidence from the interview data related to this guidance were labelled with the following codes: unable to proceed with the topic/class, inadequate technical troubleshooting and backup strategies, seeking spontaneous ICT-based solutions or delaying, and continuing the class calculatedly without interrupting. After providing detailed examples of the teacher's practices for the available codes, it can be said that Esin's proficiency level in terms of struggling with technical issues was assessed as reflective application level.

In terms of struggling with technical issues, insights about Esin's capabilities were only acquired through the interview data. To illustrate, when faced with technical difficulties, Esin's approach primarily involves utilizing alternative ICT tools or postponing the task to the next class. In her own words,

If we can't overcome, I tell the children I'll show them in the next lesson or [if] this is a worksheet or a test I'll send it to their page from the EBA. I check if they have access in the next lesson by asking them.

This approach aligns with the criteria for seeking spontaneous ICT-based solutions or delaying within the subdimension of struggling with technical issues' category. Esin demonstrates proficiency by posting e-files for students to download after school, providing an alternative solution to address technical difficulties [Struggling with technical issues; seeking spontaneous ICT-based solutions or delaying]. As this action is consistent with the rubric's criterion for the infusive application level, Esin's proficiency was categorized as seeking spontaneous ICT-based solutions or delaying.

Similarly, Esin's further statements indicate that she has the potential to further enhance her proficiency in dealing with these issues. By seeking advice from her students and their ability to provide solutions, Esin showcases her adaptability and willingness to learn from her students' knowledge. Her quick thinking and resourcefulness in utilizing alternative methods, such as transferring internet connection or troubleshooting web page errors, further highlight her proficiency in addressing technical difficulties. Although she states that she does not encounter serious situations, her proactive approach and ability to handle various technical challenges suggest a high level of proficiency in troubleshooting [Struggling with technical issues; seeking spontaneous ICT-based solutions or delaying]. However, her proficiency does not reach the highest level because she primarily relies on quick fixes and ad-hoc solutions rather than having a structured approach to technical issues that might involve more complex troubleshooting strategies.

However, her further statements suggest that she has the potential to achieve a higher level of proficiency in dealing with these issues. When asked how to overcome technical issues in the classroom, Esin replies,

I usually refer to my students who are masters of the job (laughs). Joking aside,

really, children say to almost all the problems I encounter, as if they invented the smart board, my teacher do it this way, my teacher do it, and they usually solve it. Other than that, there are situations that I can handle. For example, if the internet is disconnected, I can immediately transfer the internet of my phone on the smart board. Or let's say a web page or simulation did not open. I immediately delete the cookies and reload the page. Or I'm trying to open something in Firefox. I don't come across very serious situations.

According to these statements, Esin demonstrates highest level of proficiency in troubleshooting technical issues without interrupting the course. Her ability to prepare hard copies for internet troubles and her reliance on her students' expertise show her competence in finding effective solutions [Struggling with technical issues; continuing the class calculatedly without interrupting], aligning with the reflective application level for dealing with technical challenges.

Overall, Esin's proficiency level in handling technical issues during his teaching falls within the reflective application level. Despite the absence of specific observation data regarding Esin's efforts in struggling technical issues in the classroom, her statements provide valuable insights into her proficiency. She demonstrates a high level of proficiency in troubleshooting technical issues without interrupting the class by utilizing alternative methods effectively and relying on her students' expertise. Moreover, Esin's ability to prepare hard copies in case of technical interruptions showcases her proactive approach and readiness to handle unexpected challenges during her lessons. These practices align with the criteria for reflective application, emphasizing her high level of proficiency in troubleshooting technical issues without disrupting the flow of the class despite existence of evidence for infusive application level.

4.1.4.3.3. Infusing ICTs into teaching contexts

In this subdimension, the data was analyzed through classroom observations and semi-structured interview to gain valuable insights into Esin's proficiency strategically integrating ICT tools into his teaching practices to enhance the overall learning environment. This subdimension focuses on a range of approaches and strategies employed by the teacher to seamlessly incorporate ICTs into instructional contexts, ultimately contributing to an enriched teaching and learning experience. The codes used reflect Esin's proficiency levels in terms of infusing ICTs into teaching contexts,

which highlight the effectiveness and depth of his integration. These proficiency levels encompass the belief that ICTs offer no contribution to teaching practices, the use of basic and convenient ICT tools for instructional enhancement, flexible and selective management of ICTs for instructional purposes, and skillful use of technology to foster student independence. After providing detailed examples of the teacher's practices for the available codes, it can be said that Esin's proficiency level in terms of infusing ICTs into teaching contexts was assessed as infusive application level.

Regarding the aspect of infusing ICTs into teaching contexts, the available evidence suggests that Esin's proficiency seems to be at lower level when incorporating ICT tools into her teaching. For instance, when explaining the integration of ICTs in her lessons, Esin emphasizes the significance of active student participation and utilizes ICT tools to sustain student interest and support lesson objectives [Infusing ICT into teaching contexts; enhancing teaching through basic and convenient ICT integration]. According to her, *"The use of ICT tools keeps students engaged and helps us achieve the objectives of the lesson, at least in the overall class."* This is consistent with the rubric's criterion on enhancing teaching through basic and convenient ICT integration category, emphasizing her ability to use easily accessible ICT tools for basic teaching enhancement and student engagement.

Parallel to this, Esin also highlights the benefits of interactive discussions and students expressing themselves in class, stating, *"In classes where we have fewer lectures and students express themselves, I feel more rested, and I have more energy to dedicate to them."* These statements indicate her intention to make teaching more engaging and better supported through the strategic use of ICT tools [Infusing ICT into teaching contexts; enhancing teaching through basic and convenient ICT integration], aligning with the simple adoption level.

Likewise, Esin emphasizes the impact of engaging content and interactive screen interactions on student focus and participation in her lessons, stating, *"Because they focus on the lesson when I show them interesting content or when they interact with the screen."* She also notices a positive change in student attentiveness, reflected in their improved performance in solving questions and exams, and she remarks, *"When this happens, they listen well, and I can observe this from the questions they solve*

correctly and the grades they receive on exams.” These statements collectively imply that imply that Esin places importance on the use of ICTs for enhancing teaching and maintaining student engagement through basic and convenient ICT integration [Infusing ICT into teaching contexts; enhancing teaching through basic and convenient ICT integration], reflecting her proficiency at the simple adoption level.

Additionally, a student’s feedback as conveyed by Esin, highlights the impact of her use of ICTs, with the student stating, *“Because you show us a lot of different things on the smart board, you have us solve questions on the board, and you engage us with games.”* The student’s comment further reveals their desire for her class, as the student expressed as Esin conveyed, *“That’s why we want that class to end quickly so that your class can begin.”* These statements collectively demonstrate her efforts to enhance teaching and support student learning through the thoughtful integration of ICT tools [Infusing ICT into teaching contexts; enhancing teaching through basic and convenient ICT integration], aligning with simple adoption level of proficiency criteria. Esin effectively incorporates ICTs to actively engage students and observes positive outcomes in their learning, as evidenced by their successful problem-solving and exam performance.

On the other hand, there is evidence indicating that Esin’s proficiency may be at a higher level. For instance, Esin expressed her perception of her classroom management proficiency as follows:

I didn’t see myself as a teacher with good classroom management. However, when I compared myself to my colleagues in the teachers’ lounge, I realized that I have better control. I believe this is because I am able to capture students’ attention and engagement by incorporating activities and other instructional tools that they enjoy... This prevents serious disruptions in the classroom, and the class environment does not consist of students who sabotage the lesson. Therefore, I believe that my classroom management is effective due to the way I conduct the lessons.

This statement indicates Esin’s self-assessment of her classroom management skills and her understanding of the importance of engaging activities and instructional tools in maintaining a positive classroom environment. Her perception suggests a level of proficiency in utilizing strategies to manage the classroom effectively [Infusing ICT into teaching contexts; flexible and selective management of ICTs for student learning

and instructional management]. This aligns with infusive application level of proficiency, where teachers manage ICTs flexibly and selectively to support students' learning and instructional management.

Additional evidence was acquired from classroom observation of Esin to validate her claims. Accordingly, it was observed in one of Esin's class (Observation of Esin's 4th class session), she demonstrated proficiency in facilitating a hands-on experiment to explore the concepts of kinetic energy and its relationship with velocity and mass. Esin engaged the students by asking thought-provoking questions, guiding them to formulate hypotheses, and conducting the experiment using different materials and heights. The students actively participated, made observations, and analyzed the data to draw conclusions. Based on this observation, Esin's guidance and the students' engagement showcased a high level of proficiency in utilizing ICT tools to support student learning and instructional management, which aligns with infusive application level of proficiency. The observation data provides clear evidence of her competence in facilitating meaningful and interactive learning experiences [Infusing ICT into teaching contexts; flexible and selective management of ICTs for student learning and instructional management], where ICTs are flexibly and selectively used to enhance students' understanding of scientific concepts. The observation data provides clear evidence of her competence in facilitating meaningful and interactive learning experiences.

Overall, Esin's proficiency level can be classified as infusive application, reflecting her capability to infuse ICT tools effectively into teaching contexts. While there is evidence indicating a proficiency level at the simpler adoption stage, primarily focusing on convenience and entertainment, the overarching indications of higher proficiency emerge from her capacity to manage her classroom effectively, strategically use ICT tools to support student learning, and create interactive and engaging learning experiences. Esin's infusive application proficiency level underscores her adeptness at integrating ICT tools into her teaching practices, fostering an environment where students actively participate and benefit from ICT-enhanced instruction.

To sum up, Esin's proficiency level in enactment aligns with infusive application level.

Table 18. The proficiency levels of Esin in enactment

Name of the Subdimension/Dimension	Proficiency Level
ICT guidance	Infusive application
Struggling with technical issues	Reflective application
Infusing ICTs into teaching contexts	Infusive application
ENACTMENT	Infusive application

As seen in Table 18, within the ICT guidance subdimension, Esin demonstrates an advanced understanding of the effective use of ICT tools to engage students and enhance their learning experiences, aligning with infusive application level. In the subdimension of struggling with technical issues, Esin demonstrates reflective application level of proficiency, indicating her competence in addressing technical challenges without disrupting the flow of the class. Esin exhibits a reflective application level of proficiency. In the subdimension of infusing ICTs into teaching contexts, Esin's proficiency level aligns with infusive application, indicating her ability to enhance classroom instruction and engage students effectively through basic and convenient ICT integration. Considering her strong performance in guiding ICT use for learning enhancement and her ability to infuse ICTs into her classes by managing ICTs effectively for enhancing her instructional management and students' learning, it is reasonable to conclude that Esin's proficiency level in infusing ICTs into teaching contexts is more likely at infusive application level.

4.1.5. Comparisons and Contrasts in TPACK-P Proficiency Levels Across Teachers

This section presents a brief information on analysis of TPACK-P proficiency levels among all teachers within three educational dimensions. It emphasizes the comparison and contrast of their individual performances. These dimensions encompass assessment, planning and designing, and enactment, ultimately revealing notable distinctions and commonalities in their technology integration practices.

In analyzing the teachers' TPACK-P proficiency levels within the assessment

dimension, a noteworthy divergence in their proficiencies becomes evident. For example, while Asaf, Bora, and Cenk demonstrate a proficiency aligned with the simple adoption level, indicating their familiarity with the utility of ICT tools for identifying misconceptions, their utilization of these tools for assessing student learning needs remains limited. On the contrary, Esin distinguishes herself with a notably higher level of proficiency, categorized as infusive application. She adeptly employs various ICT tools to assess students' learning progress, skillfully adapting her instructional approach accordingly. This difference underscores the varying degrees of proficiency among the teachers in utilizing ICT tools for assessment purposes, with Esin excelling at a more advanced level.

Delving deeper into the subdimensions of the assessment dimension, a nuanced contrast in TPACK-P proficiency levels emerges. In the subdimension of understanding students' learning needs, variations are evident. Asaf, Bora, and Cenk predominantly exhibit proficiency at the simple adoption level, reflecting their reliance on basic ICT tools to address students' misconceptions and provide essential support. Esin's performance stands out, as she excels at an infusive application proficiency level. Her adept use of ICT tools allows her to assess students' learning needs, challenge misconceptions, and tailor her teaching strategies based on students' interactions with technology. Meanwhile, within the subdimension of assessment practices, the teachers' competencies remain consistent. Asaf, Bora, and Cenk continue to demonstrate simple adoption proficiency, focusing primarily on in-class formative assessments with intermittent integration of ICT tools. Once again, Esin distinguishes herself with her infusive application proficiency, effectively employing a diverse range of ICT tools for assessing student learning and enhancing her instructional approach. This dual contrast illuminates the divergence in the teachers' approaches to technology integration within the assessment dimension, emphasizing the difference in their TPACK-P proficiency levels across subdimensions.

When delving into the TPACK-P proficiency levels within the planning and designing dimension, a diversity of proficiencies is evident. For instance, Asaf consistently occupies the simple adoption category, focusing on using representations for enhancing visualization and motivation within the class. However, his teaching approach tends to lean more towards teacher-centered methods. This contrasts with

Bora, who falls under the lack of use category, emphasizing non-ICT goal setting and an inclination towards completely teacher-centered teaching. In contrast, Cenk showcases infusive application proficiency, effectively incorporating ICT tools to enhance content and visualization while maintaining a teacher-centered approach. Similarly, Esin's proficiency level within the planning and designing dimension is assessed as infusive application. She excels in curriculum design, actively engaging students in scientific exploration and concept development. While there are instances of teacher-centered elements, her overall approach leans more towards student-centered strategies.

The exploration of each subdimension within the planning and designing dimension reveals specific variations and shared tendencies among the teachers. In the subdimension of planning the class, Asaf and Bora occupy the simple adoption and lack of use categories, respectively. Asaf emphasizes using representations for visualization in a predominantly teacher-centered manner, while Bora relies heavily on non-ICT goal setting and teacher-centered teaching. Cenk excels in the infusive application category, integrating technology for content enrichment and enhanced visualization, despite differences in their teaching methods. However, Esin reaches to the reflective application level, showing her competence in using multiple ICTs to support learning of and about science. In the subdimension concerning the utilization of ICT representations, Asaf and Bora exhibit proficiency at the simple adoption level, primarily employing ICT representations for visualization. However, the proficiency level of Cenk and Esin align with the infusive application, emphasizing interactive learning support. Meanwhile, the distinctions primarily lie in their teaching methods. While Bora is the one who adopt a more teacher-centered approach, Asaf seems to be less teacher-centered and more flexible in instructional strategies. Cenk and Esin seem to lean toward more student-centered teaching approaches.

The analysis of the teachers' TPACK-P proficiency levels within the enactment dimension reveals a range of proficiencies. While Asaf and Bora demonstrate a proficiency aligned with the simple adoption level in terms of infusing ICTs into teaching contexts, indicating their understanding of the positive impact of ICT tools on teaching, Cenk and Esin excels with an infusive application proficiency level. Cenk effectively enhances the overall teaching experience through the integration of visually

appealing and interactive ICT tools, primarily emphasizing convenience and enhancement in his ICT integration for teaching. Esin's proficiency level aligns with infusive application, emphasizing her advanced understanding of the effective use of ICT tools to engage students and enhance their learning experiences.

A closer examination of the subdimensions within the enactment dimension reveals specific comparisons and contrasts among the teachers. Examining the ICT guidance subdimension, Asaf's proficiency level aligns with simple adoption, where he provides visual and verbal support to students. On the other hand, Bora demonstrates a lack of use proficiency, offering insufficient support in guiding students effectively. In contrast, Cenk and Esin demonstrate infusive application proficiency in ICT guidance, with advanced understanding and effective use of tools. Regarding struggling with technical issues, Asaf and Cenk exhibit simple adoption proficiency, showing some skills in addressing technical problems during class. On the contrary, Bora demonstrates an infusive application approach, showing adaptability and resourcefulness to address issues and maintain a smooth class flow. Esin's proficiency level reaches reflective application, indicating seamless management of technical challenges. Moving to the infusing ICTs into teaching contexts subdimension, the proficiency level of Asaf, Cenk, and Esin was infusive application, showcasing an advanced understanding of effective ICT tool use to engage students. However, Bora aligns with simple adoption level with his approach limited to basic and convenient ICT integration.

4.2. The Nature of Interplay among TPACK-P Components of In-service Science Teachers

In order to explore the nature of the interactions among TPACK-P components, the teacher's interviews and the classroom observations of their teaching were thoroughly examined through the steps mentioned in the method chapter. The data were carefully read, coded, and categorized into preestablished categories which are five TPACK-P components. The codes utilized in the analysis process consisted of both pre-existing codes derived from the TPACK literature and emergent codes that were developed from the collected data. When codes from the different TPACK-P component intersect each other (TPACK episode), they were analyzed thoroughly. Thus, through in-depth

exploration and interpretation of evidence, data became ready for further step. In reporting, the name of TPACK component and related code were depicted in brackets to enhance clarity and facilitate easy reference such as [KoA; in-class formative assessment using ICT].

In the second phase of the analyzes, the determined TPACK episodes were united to form TPACK-P maps for each teacher. The interactions between the TPACK components were depicted using the TPACK-P model after the identification of TPACK episodes. Through enumerative approach, the frequency of the interactions was revealed more clearly. By summing all the TPACK episodes generated four distinct TPACK-P maps for each participant.

In the last phase, the constant-comparative method was successfully applied after engaging in in-depth analysis and enumerative approach. Through constant-comparative method, the comparison of data across four cases yielded assertions regarding the interaction of TPACK-P components with a focus on identifying similarities and differences of data.

Thus, the findings were presented in the order of providing detailed information about the data and showcasing the number of occurrences for each interaction within each case. Additionally, the number of interplays was briefly mentioned for each interaction. TPACK-maps were displayed at the end of the findings for each case. Ultimately, assertions yielded from the data and the maps were formed.

4.2.1. Case 1: Asaf

In this section, a detailed analysis of the interplay among TPACK-P components in Asaf's case was presented by considering ten potential interactions between these components. Each interaction was explored to provide insights into the nature of Asaf's TPACK-P and how these components inform each other.

4.2.1.1. The Interaction between KoCD and KoA

As operationally defined, the interplay between KoCD and KoA involves strategically integrating technology into science lessons through the selection of ICT representations and teaching techniques aligned with curriculum objectives. It also

encompasses using ICT for assessing students' progress, employing various assessment methods, and understanding the role of technology in science class assessments. When examined Asaf's TPACK episodes including codes under the categories of KoCD and KoA, there are several evidence reflecting KoCD-KoA interplay.

In one of Asaf's classes (Observation of Asaf's 13th class session), it was observed that Asaf assigned a task to the students to draw or design an online model of a vehicle that minimizes air and water resistance after completing all subtopics related to air and water resistance in the force and energy unit. He also opened and displayed a PDF poster that explained the task details, the platforms available for students to use, and provided links to tutoring videos. Here, this observation highlights the interaction between KoCD and KoA, suggesting that the KoCD informed the KoA. Asaf's design of the assignment, incorporating ICT (pdf poster) and aligning it with the science curriculum goals, showcases the interplay between the knowledge of curriculum design and the knowledge of assessment. The integration of ICT-based assessment strategies [KoA; Assessment based on product development] and the utilization of appropriate design elements [KoCD; designing model/product] reflect the teacher's understanding of how these components can complement each other to enhance the learning experience in the science class. Accordingly, Asaf's design of the assignment, including the use of ICT and aligning it with the science curriculum goals, demonstrates how the choices made in curriculum design influence the assessment strategies employed in the science class.

Along with these observations,' Asaf's statements also shed light on his ability to design science classes using ICT and assess students using ICT-based tools. For instance, when he mentions "*Other than that, I sometimes play the game of the Millionaire competition adapted for science*", it can be seen as an illustration of the interplay between KoCD and KoA. This is because his implementation of the educational game called the Millionaire [KoCD] within the classroom incorporates in-class formative assessment strategies [KoA]. As a result, this approach creates an engaging and enjoyable learning experience for the students. In essence, Asaf's statement may serve as evidence of the positive impact of combining KoCD and KoA in science education. The use of the educational game (KoCD) is integrated into the

in-class formative assessment strategies. Likewise, Asaf further stated that he could plan the design of his science class based on utilizing ICT-based assessment strategies. In his own words,

I make adjustments according to the class level. For instance, in a high-level class, I bring extra materials like tests or worksheets. We discuss and solve them on the smart board. Sometimes, I provide them at the beginning or end of the topic. I plan this according to the class's situation. I try to assess their understanding at the beginning of the semester or unit using interactive materials such as questions and answers, animations, videos, or visuals.

Accordingly, Asaf's consideration in designing his science class with ICT [video, animation for KoCD] is influenced by his formative assessment practices [in-class formative assessment for KoA]. After exploring the level of the students, he stated that he is able to adapt his teaching methods such as providing extra materials and assessments like tests and worksheets for advanced students. This showcases the interplay between KoCD and KoA components. Furthermore, using interactive materials such as videos, animations, and visuals at the beginning of the term or unit to assess students' understanding demonstrates how the utilization of formative assessments informs his curriculum design decisions.

Similarly, there is another example to KoCS-KoA interplay in Asaf's statements. When he explains his planning of science class, he stated,

I expect them to embrace technology. As you know, we had a pandemic, and we conducted our lessons using technology at home. For scientific literacy, they need to have some level of technology knowledge. That's why I want them to develop their technology skills. For instance, in the design assignment I gave, I initially introduced them to applications like Tinkercad and 3D modeling at a surface level, and then I assigned them a task to explore and develop their skills on their own.

Asaf states that he wants his students to accomplish some tasks, specifically model designing, due to his recognition of the importance of technological literacy for science education [KoCD; science program goals]. By assigning a design project and introducing applications like Tinkercad and 3D modeling [KoA; assessment based on product development], he aims to empower students to explore and improve their technological competencies independently. Additionally, his focus on students' learning outcomes illustrates how KoCD informs and shapes the implementation of

KoA.

In summary, Asaf's observation and interview data revealed that the interplay between KoCD and KoA is evident in various ways. Through the analysis of the data, the number of these interplays was counted as a total of four interplays. Both components inform and influence each other, suggesting to a dynamic relationship that enhances the design of science classes with technology integration while shaping the implementation of effective assessment strategies.

4.2.1.2. The Interaction between KoCD and KoPiT

Interaction between KoCD and KoPiT refers how explicitly teacher guides and engages their students in ICT-infused learning that is planned to use ICT-based representations, teaching strategies, and learning tasks as well as knowing factors affecting the ICT-based design in accordance with science curriculum. When the related TPACK episodes of Asaf were examined, evidence of KoCD-KoPiT interplay became evident.

During observing one of Asaf's class (Observation of Asaf's 1st class session), it was observed that Asaf opened an e-experiment simulation where students were actively engaged in a drag-and-drop experiment [KoCD; interactive experiment] as ICT-infused representations. The students were supposed to drag related boxes to conduct this experiment related to weight. However, Asaf noticed that there was a malfunction in smart board's screen leading not to accomplish this. Then, he told the students that he was going to conduct the experiment by himself. Here, Asaf's choice of using an animation with a simulated e-experiment reflects his effort to condition and integrate appropriate ICT tools or applications [KoPiT; adapting to ICT tools or applications] into his curriculum design. However, due to technical limitations with the smart board, he adapted his plan and conducted the e-experiment demonstration himself to ensure the learning experience proceeds effectively. This indicates how his knowledge of practical teaching guides him in addressing challenges related to ICT use. Asaf's action of taking important notes during the demonstration also highlights his instructional management skills and the ability to achieve the target learning goals [KoPiT]. Thus, this provides a good example on how his KoCD and KoPiT interact to create a meaningful and technology-infused learning experience.

In another class of Asaf (Observation of Asaf's 3rd class session), it was observed that after solving various related practice questions about force and the amount of extension in the spring, he explained that he had a tool for students to conduct experiments and observations on such topics. Asaf showed the students a way to find resources about the lesson. He demonstrated how to navigate to Google and type the keyword 'phet', then accessed the website and opened the simulations related to their courses. Next, he initiated the 'Masses and Springs' simulation by stating, 'Let's look at a simulation related to our lesson today.' Asaf took charge of starting and overseeing this initial simulation. He explained the gravity-weight relationship to his students by manipulating the variables. His ICT guidance approach was primarily focused on providing visual and verbal support to the students. He demonstrated how to access online resources and open simulations related to the lesson. Based on these observations, it is evident to say that Asaf skillfully demonstrated an effective interplay between KoCD and KoPiT. He guided the students in finding relevant resources by demonstrating how to search on Google and access the 'phet' website for simulations related to the lesson, exemplifying his commitment to leading students in using ICT [KoPiT; guiding students to learn using ICT]. Then, he introduced the simulation 'Masses and Springs' by integrating the simulation into the lesson's context [KoCD; simulation]. Additionally, his action on doing the simulation points to employing guided lecturing technique [KoCD; guided lecturing] where there is engagement in meaningful question-and-answer interactions. Thus, Asaf's actions indicates how his KoPiT informs and shapes his KoCD.

Moreover, Asaf's aim of familiarization of his students with ICT use also allowed him to interact with ICT, contributing to a dynamic and active learning experience for his students. For example, Asaf opened an interactive experiment in an animation to explain the relationship between elastic potential energy and displacement (Observation of Asaf's 10th class session). The animation involved an iron ball that compressed a spring fixed to the wall. One student stood up and tapped the smart board screen, squeezing and releasing the marble, while Asaf instructed the students to make careful observations of the changes. Afterwards, Asaf guided the student on the smart board to use the pen tool and record the findings in an available space on the screen. The student noted the following observations: 'It moves 8 m when compressed by 4

cm' and 'When compressed by 5 cm, it moves 10 m.' Later, another experiment was conducted on the smart board involving a flexible rubber cover and a ping pong ball (Figure 16).

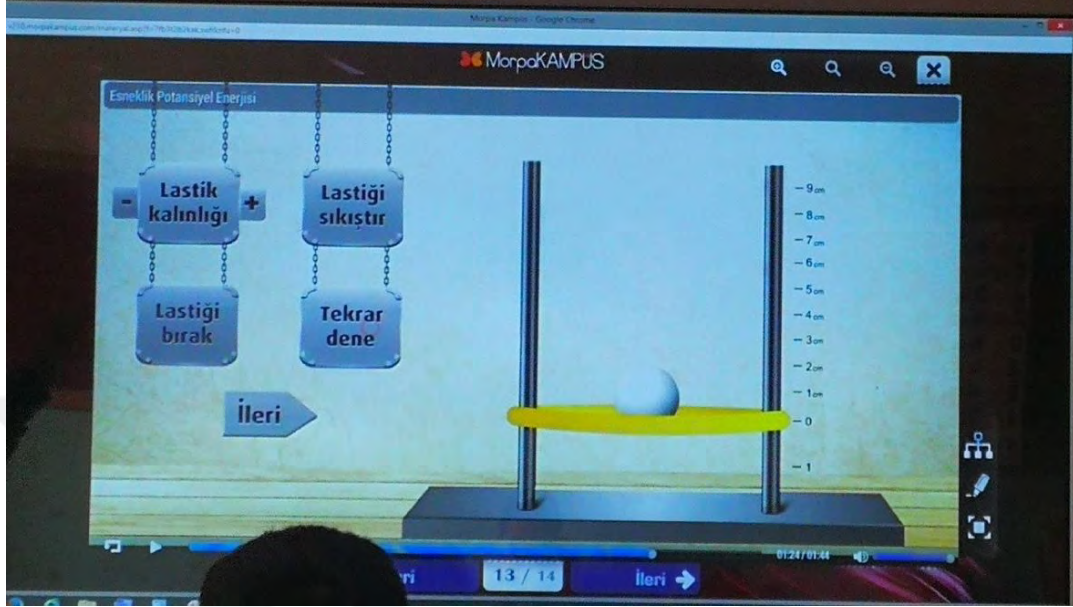


Figure 16. The image of one of the moments of Asaf's virtual experiment demonstrating the relationship between elastic potential energy and displacement

A student performed the experiment, and similar to the previous one, he directed the student to use the pen tool to record the measurements in an available area. The student wrote the following findings: 'When dropped from 3 meters, it goes down 3 units' and 'When released from 1 meter, it goes down 1 unit.' According to these observations, Asaf's aim of familiarizing his students with ICT use [KoPiT; guiding students to learn using ICT] was evident as he opened an interactive experiment in an animation to explain the relationship between elastic potential energy and displacement. By utilizing a virtual experiment as an ICT-infused representation [KoCD; virtual experiment], Asaf guided his students to actively participate in the experiment and record their measurements. This observation clearly demonstrates how Asaf's knowledge of practical teaching [KoPiT] informs his curriculum design choices [KoCD] for creating a well-structured and technology-infused science lesson. Thus, Asaf's intentional integration of KoCD with KoPiT highlights the thoughtful interplay between these two components in his teaching practices.

Align with observation data, Asaf's statements during the interview shed light to further KoCD-KoPiT interplay. For example, when he explains the importance of ICT use in science learning, Asaf states,

... sometimes it provides safety. For example, we were going to conduct an experiment to observe the release of hydrogen gas. We used to do this in a physical laboratory before, but I realized there were risks involved. So, I found a similar experiment on YouTube and showed it to the students. It was a visually impressive demonstration when zinc particles reacted with hydrochloric acid. This really caught the students' interest, and we didn't encounter any safety issues. I can say that ICT tools, in a way, save the day in such situation.

From these statements, it is evident that Asaf recognizes the advantages of using ICT [KoPiT; ICT advantages/disadvantages] in his teaching practices. He mentions a specific example where he decided to demonstrate the observation of hydrogen gas release through a chemical reaction using zinc particles and hydrochloric acid. To ensure safety and still engage the students, he found a video of the experiment on YouTube and showed it to the class. Asaf's use of videos as ICT-infused representations [KoCD; video] allowed him to enhance the learning experience by avoiding potential hazards while maintaining the students' engagement. This demonstrates how Asaf's KoPiT informs his curriculum design choices (KoCD) to ensure effective and safe science learning experiences for his students.

Not only awareness of ICT use advantages, but awareness of science program goals seems to be important for Asaf's class design according to interview data. That is, Asaf expressed his desire for his students to develop a fondness for technology and emphasized the importance of integrating technology skills into their scientific literacy. He acknowledged the significance of technology knowledge in achieving scientific literacy and aimed to enhance his students' technology usage skills. As part of this approach, he provided a design assignment where he initially guided students [KoPiT; encouraging student use of ICT] to familiarize with applications like Tinkercad and 3D modeling [KoPiT; guiding students to learn using ICT]. He encouraged them to explore and further develop their skills independently. Furthermore, Asaf revealed his intentions to focus on his students' learning outcomes and understanding [KoCD; science program goals]. He aimed to ensure that they grasp the concepts and achieve the learning objectives of the class [KoCD; learning objectives of the class]. By combining these components, Asaf's KoPiT informs and

shapes his KoCD to create a dynamic and technology-infused learning experience for his students.

In summary, the data indicates Asaf's two-way interactions between KoCD and KoPiT components. He effectively incorporates technology to familiarize students with ICT use and fosters their technology skills alongside scientific literacy. Asaf's guidance encourages independent exploration, aligning with science program goals and learning objectives. Through the analysis of the data, the number of these interplays was counted as a total of eleven interplays. The data demonstrated a dynamic interplay between KoCD and KoPiT, where each component informed and influenced the other.

4.2.1.3. The Interaction between KoCD and KoL

'The interplay between KoCD and KoL refers to taking into consideration of students' cognitive development, learning difficulties, learning preferences when designing and planning ICT-based science class in terms of utilizing appropriate ICT representations, teaching strategies, and learning activities in accordance with science curriculum. Upon analyzing TPACK episodes and codes under the categories of KoCD and KoL, multiple instances reflecting the KoCD-KoL interplay were observed in Asaf's data.

Asaf's instructional approach highlights evidence of interplays between KoCD and KoL. In one of his classes (Observation of Asaf's 9th class session), it was observed that Asaf started an animation video while reminding the students of the concepts covered in the previous lesson by saying 'In the previous lesson, we talked about the varieties of energy and the properties of potential and kinetic energy.' Meanwhile, he tried to locate a specific moment in the animation video [KoCD; animation] on the smart board. After he set that moment on the video, two children appeared on the screen, one with a ball in his hand and the other pulling a box. Asaf asked about the types of energy observed on the screen as well as their subtypes such as potential energy, gravitational potential energy, or elastic potential energy, and what these energies depend on. Thus, it appears that he aimed to assess students' comprehension and address any potential misconceptions from the previous lesson [KoL; checking students' background knowledge]. In this example, Asaf's use of animation (KoCD) informs and influences his approach to checking students' background knowledge using ICT (KoL). By using the animation to describe concepts, he sets the stage for

assessing students' understanding of the previously covered topics. The animation helps students visualize and recall the concepts. In this way, KoCD informs and guides KoL as an effective method for assessing and addressing students' learning needs.

Similarly, in another class (Observation of Asaf's 12th class session), Asaf integrated various teaching strategies, including animation and guided lecturing to facilitate learning and check students' background knowledge using ICT. He started by playing an animation [KoCD] related to the topic. While watching the animation, Asaf asked thought-provoking questions like 'How can we say energy is lost due to friction?' and 'If mechanical energy is conserved, why is there a mention of loss in this topic?' The students responded by explaining that energy is converted into heat energy due to friction. Asaf guided the discussion and concluded that energy is not lost; rather, it is transformed into another form. Later, a rolling ball came to a stop in the animation, and he asked the class why it stopped. The students offered different answers, including friction with the ground, friction with the air, and gravity. Asaf encouraged further analysis by resuming the animation and showing a force applied to a box with a friction force in the opposite direction. Then, he showed a golf ball rolling on sand and a hockey ball on ice. The students observed that the golf ball stopped quickly on sand, while the hockey ball continued to move on ice for a longer time. When Asaf asked why this happened, one student explained that there is less friction on ice because its surface is smoother. Asaf praised the student's answer and expressed surprise that someone remembered it, to which the student replied that they learned it in the fifth grade. In this example, the Asaf's use of guided lecturing [KoCD] showcases a more teacher-centered approach to checking students' background knowledge using ICT (KoL). Asaf effectively incorporates the animation and thought-provoking questions to lead the discussion and guide students through the learning process. By providing explanations and guiding the class interactions, Asaf assesses students' understanding of the concept and addressed potential misconceptions. While the use of guided lecturing allows for structured content delivery and ensured important points were covered, it also played a crucial role in guiding students' critical thinking and conceptual understanding. This interplay between KoCD and KoL demonstrates how Asaf's teacher-centered approach effectively integrated ICT to promote a deeper understanding of the topic and guide students' learning.

The interview conducted with Asaf provides further evidence for KoCD-KoL interplay. In line with observations, Asaf states how he utilizes ICT tools to inform his knowledge on students. Asaf highlights that they (his colleagues in the same school) generally prefer to use Morpa during the class, but he occasionally utilizes EBA. He initiates the lesson by using questions related to the topic, sometimes using pre-existing questions from Morpa or creating their own [KoCD; questioning]. Asaf states, *“I try to understand the students’ prior knowledge from there”*. Moreover, Asaf incorporates animations and videos into the lesson [KoCD]. He mentions, *“I can show an event in the videos, and then I try to assess by asking questions and receiving answers”*. Through these strategies, he actively employs ICT tools to gauge the students’ background knowledge and assess their comprehension [KoL; checking students’ background knowledge using ICT]. This approach allows him to effectively tailor the lesson content to match the students’ existing knowledge, thus informing and influencing his instructional decisions and content selection.

In summary, Asaf’s teaching approach reflects a dynamic interplay between KoCD and KoL. Through his use of animation and guided lecturing, Asaf effectively checks students’ background knowledge and addresses potential misconceptions. He employs thought-provoking questions to encourage critical thinking and guides students in understanding complex concepts. Asaf also recognizes ICT-based motivational strategies, such as incorporating humor and assigning research projects. By actively engaging students and assessing their comprehension through ICT, Asaf tailors his lessons to match their existing knowledge, thus informing and influencing his instructional decisions and content selection. The total number of bidirectional interplays was estimated as eight.

4.2.1.4. The Interaction between KoCD and KoSC

In line with the operational definitions, the interplay between KoCD and KoSC The interplay between KoCD and KoSC requires a deliberate selection of ICT representations, teaching techniques, and learning activities aligned with science curriculum objectives. This interaction involves leveraging expertise in using ICT to effectively deliver challenging science content and enhance comprehension. Upon analyzing Asaf’s TPACK episodes associated with the specific codes within KoCD

and KoSC, the presence of this interplay between the two components became evident.

During his teaching (Observation of Asaf's 4th class session), it was observed that Asaf sometimes uses ICT tools to make his students grasp the science content better. For example, when Asaf was continuing the topics gravity, he asked his students 'If every mass exerts a force of attraction, why don't we attract planets towards us?' In response, a student offered an explanation related to the absence of a core capable of generating gravity. The student's question pertained to why planets were not attracted to us if every mass exerted a force of attraction. Recognizing the need to address this query comprehensively, Asaf employed a video presentation [KoCD; video] to offer an alternative perspective and aid the student's grasp of the concept [KoSC; facilitating understanding of the content]. This interaction highlights how Asaf strategically integrates ICT tools to enhance content comprehension and actively engage with students.

Similarly, Asaf opened another video for comparison of weight in Moon and Earth (Observation of Asaf's 4th class session). He provided explanations while addressing a question asked in the video [KoCD; video] displayed on the smart board. During showing the video, Asaf often paused it to draw attention to the contrasting weights of objects on the Moon and Earth [KoSC; facilitating understanding of the content]. Displaying models of a globe and an apple on the screen, with the weight of the apple labeled as 6N on Earth and 1N on the Moon, he prompted students to think why the same apple exhibited different weights. Students thought the difference was because of the gravity on the Moon and Earth. Using this idea, Asaf gave an example: imagine a 100g apple taken from Earth to the Moon, and asked students what they think would happen to its weight. Some students anticipated a reduction in weight by one-sixth due to decreased gravity on the Moon while others believed the weight would remain constant. He adeptly interacted with these answers while exploring the fundamental ideas of mass and weight and praising a student for clarifying the difference between the two. Asaf further addressed misconceptions by emphasizing that mass and weight should not be used interchangeably and underscored the effect of gravity on weight. The actions and approach that Asaf exhibited during these processes suggest inclination towards guided lecturing, which aligns with a teacher-centered instructional style. Thus, Asaf's utilization of strategies to facilitate content

understanding [KoSC] informs his tendency towards guided lecturing [KoCD], illustrating the influence of KoSC on his instructional approach.

In summary, the data gathered from the observations suggests that Asaf's teaching approach effectively integrates his KoCD with his KoSC. He skillfully uses technology and instructional strategies to deliver science content in a way that aligns with curriculum goals. Asaf's ability to employ ICT tools to facilitate student understanding of complex scientific concepts demonstrates the synergy between his KoCD and KoSC. This integration of curriculum design knowledge and subject content knowledge allows him to adapt his teaching methods to meet students' needs and enhance their comprehension of the material. In terms of the number of these interactions between KoCD and KoSC, a total of two interactions were seen, which are considered as two-way interactions.

4.2.1.5. The Interaction between KoPiT and KoA

As operationally defined, the interaction between KoPiT and KoA involves teachers' knowledge in addressing challenges related to ICT use, their instructional management skills tailored to student needs, and their ability to guide students effectively in using technology for learning when utilizing technology for designing and conducting science assessments. When examined Asaf's TPACK episodes including codes under the categories of KoPiT and KoA, there are several evidence reflecting KoPiT-KoA interplay.

During the observations of Asaf's classes, there are plenty of instances where KoPiT-KoA interactions were clearly seen. The most often observed interactions were his actions regarding to in-class formative assessment especially when he encourages his students to use of ICT tools. To illustrate (Observation of Asaf's 6th class session), most of the exercise questions that Asaf displayed on the smart board seemed to be chosen to allow students to solve them interactively on the smart board themselves. Asaf used an online learning platform called Morpa Campus to show exercise questions about potential and kinetic energy. At first, there were true-false questions. If a student at the smart board got one right, they could answer one more, but only up to two questions. Then, there were fill-in-the-blank questions. Students had to pick the right answer from a list and drag it to the blank space in the question. After that, there

was a ranking question where students had to arrange three balls by their potential energy, from highest to lowest, as they aimed for a goal. These pieces of evidence demonstrate how Asaf's efforts in conducting in-class formative assessments [KoA], including the use of question types such as true-false, fill-in-the-blank, and ranking, contribute to his expertise in guiding students' use of ICT [KoPiT; guiding students to learn using ICT], as students actively engage with ICT tools such as smart boards during these assessments.

In another class (Observation of Asaf's 11th class session), Asaf skillfully utilized the smart board to guide his students through a formative assessment activity centered on potential and kinetic energy (Figure 17). As students interacted with these tools,

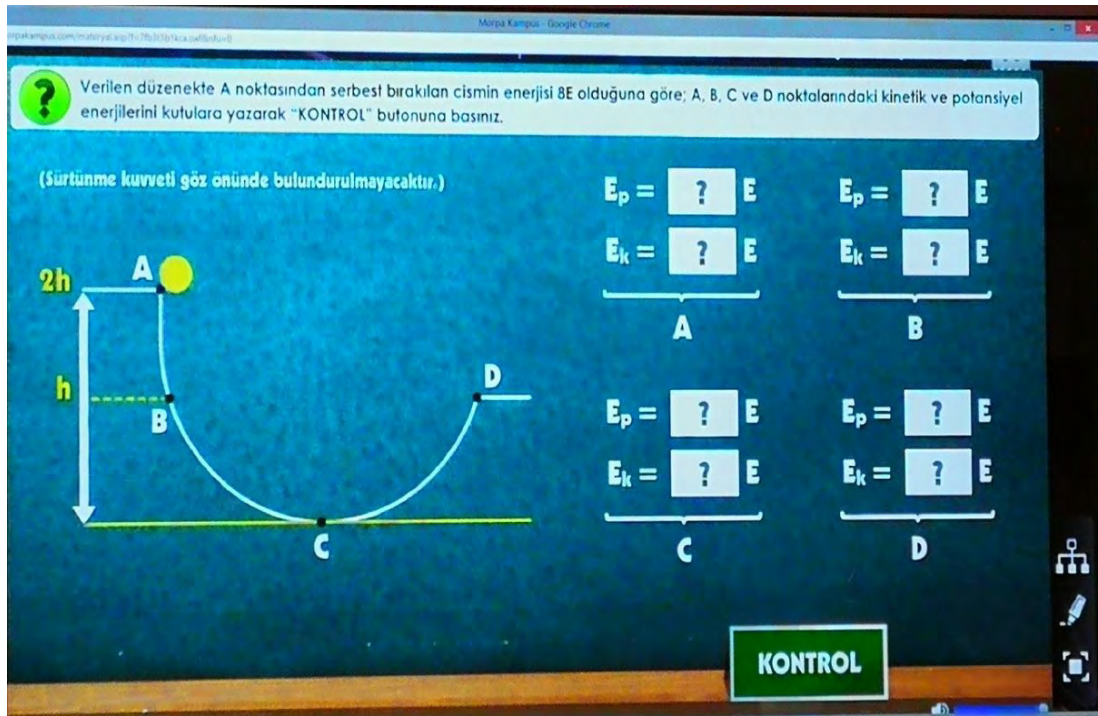


Figure 17. Image of close-ended question opened on the smart board by Asaf

Asaf encouraged them to think critically about the energy concepts presented in the questions and provided guidance on how to arrive at the correct answers. He prompted one student to activate the touch keyboard and input their responses to facilitate an interactive learning experience [KoPiT; guiding students to learn using ICT]. Moreover, Asaf's engagement with students in analyzing and solving a closed-ended question demonstrated his adeptness in conducting in-class formative assessments [KoA]. This observation clearly indicates an interaction between Asaf's guidance for

students in using ICT and his expertise in in-class formative assessments, emphasizing the dynamic interplay between these two components. Asaf's ability to effectively analyzing and solving closed-ended questions is utilized to guide students in their learning process using ICT tools. This implies that his proficiency in assessment practices contributes to his instructional strategies involving technology use. Thus, KoA appears to inform KoPiT in this instance.

In another class of Asaf's (Observation of Asaf's 13th class session), it was observed that Asaf assigned a task to the students to draw or design an online model of a vehicle that minimizes air and water resistance after completing all subtopics related to air and water resistance in the force and energy unit. He also opened and displayed a PDF poster that explained the task details, the platforms available for students to use, and provided links to tutoring videos. Upon examining these observations, it appears that Asaf initiates a project-based assessment task [KoA; assessment based on product development] to inform his students about an upcoming assignment linked to the learning objective. While doing this, he guides on how students can approach this assignment using ICT tools helps them to better understand what is requested [KoPiT; guiding students to learn using ICT]. Thus, Asaf's use of model design assessment task (KoA) informs his instructional practices (KoPiT) by guiding students on how to effectively utilize ICT tools.

In line with this, Asaf clarifies his intention during the interview. While explaining how he guides his students when conducting assignments, Asaf highlights the following:

I want to improve their technology usage skills. For instance, in the design assignment I gave, I first introduced applications like Tinkercad and 3D Modeling briefly, and then I assigned them a task to explore and develop these tools further on their own.

These statements confirm that Asaf's guidance efforts on assignments based on product development assessments using Tinkercad and 3D Modeling software [KoA; assessment based on product development] help him encourage his students to use ICT tools [KoPiT; encouraging student use of ICT]. Accordingly, it appears in this case that Asaf's KoA informs his KoPiT since he intentionally uses assessment tasks to promote ICT tool utilization and skill development among his students.

In summary, the findings indicate a dynamic interplay between KoA and KoPiT, where Asaf's expertise in assessment practices influenced his instructional strategies involving technology use. Asaf's use of ICT in assessments and guidance for students indicated a potential interplay between these components, suggesting that KoA may inform KoPiT to some extent. However, the precise direction of influence and the depth of this interaction remain open to interpretation. Since Asaf aims to develop his students' ICT literacy, it is most likely to expect that his KoA enhances his KoPiT. In terms of the number of these interactions between KoPiT and KoA, a total of twenty-nine interactions were seen in Asaf's data.

4.2.1.6. The Interaction between KoPiT and KoL

The interplay between KoPiT and KoL was operationally defined as taking into consideration of students' cognitive development, learning difficulties, learning preferences when applying both instructional management skills and infusing ICT into teaching context effectively. However, it is important to note that despite the operational definition's emphasis on this interplay, there were limitations in gathering comprehensive evidence through observation alone. Instead, a limited amount of evidence was obtained only from the interview to explain KoPiT-KoL interplay. Based on the Asaf's interview data, there was evidence for KoPiT-KoL interplay.

When describing learning difficulties of his students during technology-integrated teaching, Asaf highlights that he could understand how his students face learning difficulties when he encourages them to solve online assignments. According to Asaf, *"Sometimes, I can clearly understand how much of the homework or tests I send through EBA they have completed by checking. It provides us with a question-by-question report, and I can quickly and clearly see where they struggled."* This demonstrates a clear interplay between his knowledge of encouraging students to use ICT and his awareness of students' learning difficulties with ICT (KoL). Asaf's encouragement of students to engage with technology for learning purposes [KoPiT] not only informs him about their progress but also allows him to identify areas where they encounter challenges, thus influencing his instructional strategies to address these difficulties more effectively [KoL; awareness of students' learning difficulties with ICT]. This interplay highlights the significance of considering students' learning

difficulties when integrating ICT into teaching practices, ultimately enhancing the learning experience.

Similarly, the interplay between Asaf's knowledge of encouraging student use of ICT (KoPiT) and his awareness of adapting to students' learning styles with ICT and recognizing ICT-based motivational strategies for students (KoL) is evident in his teaching approach. In his own words, Asaf explains,

Sometimes, some students tend to learn more by listening, some by seeing, and some through interaction. We strive to cater to all of them, appealing to both their visual and auditory senses. I try to complete as many activities as possible on Morpa. I might be a bit behind schedule, I'm aware, but I work on finishing all the activities, both visually and auditorily. I place great importance on individually inviting students to the board. I encourage them to do so because it boosts their self-confidence when they see what they are capable of. ... Sometimes, I resort to game-like activities as well. For instance, when I use the spinning wheel application to choose who goes to the board, they become very happy, excited in a positive way. They enjoy it, so even though it takes a bit of time, I try to do it. Apart from that, I sometimes play music. Especially when they are taking notes, I play a song of their choice through my Bluetooth speaker. Sometimes, I let a student who gives a great answer to a challenging question choose the song. They put in the effort just to be that person.

Asaf acknowledges that students have varying learning preferences and tendencies, some benefiting more from auditory learning, others from visual or interactive methods. He strives to cater to all these preferences by using a combination of visual and auditory materials. For instance, Asaf actively engages with Morpa's online activities, completing them both visually and auditorily, demonstrating his commitment to embracing diverse learning styles [KoL; adapting to students' learning styles with ICT]. Moreover, his practice of individually inviting students to the board exemplifies his encouragement of interactive learning and boosting students' confidence [KoPiT; encouraging students to use ICT]. Additionally, Asaf occasionally employs game-like activities such as the spinning wheel to motivate and excite students positively [KoL; recognizing ICT-based motivational strategies for students]. He also plays music that allows students to listen to their preferred songs through a Bluetooth speaker. Furthermore, he leverages student achievement by letting them choose a song as a reward. In this way, Asaf's pedagogical practices reflect a harmonious blend of encouraging students to use ICT tools [KoPiT] and recognizing and adapting to students' learning styles with ICT-based motivational strategies

[KoL]. Thus, both components, KoPiT and KoL inform and influence each other to create a dynamic and engaging learning environment. Asaf's use of ICT tools is influenced by his recognition of students' learning styles. In turn, his use of ICT-based motivational strategies is enhanced by his encouragement of ICT use. This bidirectional interaction contributes to the overall effectiveness of his teaching approach.

In summary, Asaf's teaching approach reflects a dynamic interplay between KoPiT and KoL. He actively encourages students to engage with ICT tools for learning, which not only informs him about their progress but also helps him identify and address their learning difficulties. Simultaneously, Asaf recognizes the diverse learning styles and preferences among his students to adapt his teaching methods accordingly and to employ ICT-based motivational strategies. This bidirectional interaction enhances the overall learning experience that results in creating a dynamic and engaging environment that caters to individual needs and boosts students' confidence. In terms of the number of these interactions between KoPiT and KoL, a total of five interactions were estimated.

4.2.1.7. The Interaction between KoPiT and KoSC

The interplay between KoPiT and KoSC involves integrating pedagogical expertise for technology-enhanced science lessons, effectively leveraging ICT to deliver challenging science content. This includes addressing ICT challenges, guiding student ICT use, and skillfully managing the instructional process to facilitate a deeper understanding of science topics. While most of the data centers around the subject content taught, the primary focus of KoSC extends to encompass the teacher's knowledge regarding the harmonious integration of content and ICT tools, as well as their efforts to facilitate students' understanding. However, limitations in gathering comprehensive evidence on KoSC through Asaf's observation and interview data resulted in only one piece of evidence to explain this interplay.

During the observation one of his classes (Observation of Asaf's 6th class session), Asaf allowed a student to answer a question and provided guidance on how to approach it effectively. First, he intervened to highlight that reading the question aloud before addressing the premises might be misleading. Then, Asaf turned to the class to discuss

the proper approach, where a student suggested reading the question first and then the given information. Asaf affirmed this approach by emphasizing that it is true. When the student went to the smart board to solve the question, Asaf guided them by using question words like ‘why’ and ‘because’ to foster a cause-and-effect relationship. This interaction illustrates how Asaf combines his pedagogical knowledge by guiding the student on the best approach to tackle the question with the use of ICT [KoPiT; guiding students to learn with ICT]. He also effectively employs his subject content knowledge by clarifying the logical reasoning behind the student’s approach, aiming to enhance the understanding of science content within the context of exams [KoSC; facilitating to understanding the content]. This interplay aids in guiding students to learn with ICT (KoPiT) while facilitating their understanding of the content (KoSC), ultimately contributing to a more effective learning experience. Thus, KoPiT informs KoSC by providing strategies and tools to better convey, explain, and guide students in effectively solving and understanding subject content, particularly when tackling science questions. The number of interactions between KoPiT and KoSC was estimated as one.

4.2.1.8. The Interaction between KoA and KoSC

As operationally defined, KoA-KoSC interplay refers to the effective utilization of appropriate formative assessment strategies in conjunction with ICT tools, considering the alignment and appropriateness of subject content delivered with ICT. This interplay involves assessing student understanding and progress during the learning process to ensure that the chosen ICT tools enhance the clarity and comprehension of subject content. While summative assessment through ICT may not be common or permitted in the observed context, the emphasis here is on formative assessment practices that not only gauge learning but also facilitate a deeper understanding of the subject matter. Although most of the data contains information about the subject content that the teacher teaches, the primary focus of KoSC extends to encompass the teacher’s knowledge regarding the harmonious integration of content and ICT tools, as well as their efforts to facilitate students’ understanding of the subject matter. When examining Asaf’s TPACK episodes, several instances of evidence reflecting the KoA-KoSC interplay were identified within the codes under the categories of KoA and KoSC.

In one of his classes (Observation of Asaf's 6th class session), Asaf's observation data reveals a clear interplay between his KoSC and his KoA. During the class, Asaf intervened by guiding students on how to read and approach a multiple-choice question with premises effectively to point out that misinterpretation can lead to errors when he opened such a question related to weight of objects in different planets from a digital notebook. He emphasized the importance of reading the question thoroughly and understanding it. At first, Asaf asked to class to get informed how they approach to solve such questions. Then, he told them reading the question sentence first, then other information such as premises and question data should be read. He also noted that this approach will be highly beneficial not only in their current classroom activities but also in their upcoming exams. This intervention showcases Asaf's commitment to facilitating his students' understanding of the content [KoSC] by instructing them on proper reading and comprehension techniques. Besides, by observing how students approach questions and identifying any misconceptions or difficulties they have, Asaf seems to adapt his teaching strategies and subject content delivery to address these specific needs more effectively. Simultaneously, it also reflects his utilization of in-class formative assessment [KoA] to ensure that students grasp the material effectively. In other words, Asaf knows what students need to understand about interpreting questions, so he intervenes to provide guidance during the assessment. His KoSC informs the strategies he employs for formative assessment. Thus, there is a bidirectional interplay between KoSC and KoA, where Asaf's approach to content delivery and formative assessment mutually reinforces each other.

Similar example was observed when introducing students to solving graph-based questions by Asaf (Observation of Asaf's 11th class session). He skillfully utilized the smart board to create a formative assessment activity centered on potential and kinetic energy. Again, Asaf himself clarified mostly verbally how to interpret such graph-based questions by pointing out the critical points of the question on the smart board to understand the complex content [KoSC; facilitating to understanding the content]. Moreover, Asaf's active engagement with students in analyzing and solving a closed-ended question demonstrated his adeptness in conducting in-class formative assessments [KoA]. Thus, this instance further emphasizes the bidirectional interplay between Asaf's deep subject knowledge and his effective formative assessment

strategies.

In summary, Asaf's teaching practices reveal a bidirectional interplay between his KoA and his KoSC. He effectively employs formative assessment strategies to gauge students' understanding and aligns these assessments with ICT tools to ensure clarity in subject content delivery. Asaf's interventions, such as guiding students in interpreting complex questions and utilizing smart board-assisted formative assessments, exemplify this interplay. Through these actions, Asaf not only assesses students' understanding but also adapts his teaching strategies to address specific needs effectively, which is informed by his deep subject knowledge. This emphasizes how KoA and KoSC mutually reinforce each other. In terms of the number of these interactions between KoA and KoSC, a total of two interactions were seen in Asaf's data.

4.2.1.9. The Interaction between KoL and KoA

As operationally defined, KoL-KoA interplay refers to the dynamic interaction between a teacher's understanding of their students' cognitive development, learning difficulties, learning preferences, and background knowledge, all in the context of utilizing ICT-based formative assessments. This interplay involves teachers using their knowledge of students to design and implement effective assessment strategies that align with students' unique characteristics and needs. Summative assessments through ICT are not allowed, so the primary focus is on how teachers adapt their assessment practices to enhance student learning experiences using formative assessment within the ICT environment. When examined Asaf's TPACK episodes including codes under the categories of KoL and KoA, there is limited number of evidence reflecting KoL-KoA interplay.

In Asaf's interview data, there is a notable interplay between his KoL and his KoA. This is evident in how Asaf recognizes and effectively utilizes ICT-based motivational strategies to engage his students in the learning process. For instance, he states that he occasionally incorporates a version of the 'Who Wants to Be a Millionaire?' game adapted for science topics. In this game, students are presented with multiple-choice questions related to the topic. When a student hesitates or is unsure of an answer, Asaf introduces a new rule called 'joker'. This allows the student to choose a classmate to

give the right answer. He states this as *“For example, the next student wasn’t sure about the answer, so I gave a joker. I told them they could choose any classmate they wanted to get the answer from. They loved this idea”*. This approach not only increases student engagement but also fosters a supportive classroom atmosphere [KoL; recognizing ICT-based motivational strategies for students]. Therefore, Asaf’s understanding of his students’ preferences for interactive and engaging activities informs his use of ICT-based motivational strategies. Simultaneously, these strategies serve as in-class formative assessments [KoA], gauging student understanding and encouraging participation. Thus, the interplay between KoL and KoA is evident as Asaf leverages his knowledge of his students to enhance their learning experience through effective motivational techniques.

In Asaf’s interview data, there is further piece of evidence reflecting the interplay between his KoL and KoA as he adapts his teaching methods to accommodate different learning styles using ICT. In response to the question how he assesses his students learning progress, he states,

In fact, it can vary depending on the class’s level. For my seventh-grade class this year, for example, the students are at an average to slightly below average level. Therefore, the teaching approach involves less multiple-choice test-solving and more content explanation and exercise questions solving.

Accordingly, Asaf’s teaching approach varies based on the class’s level especially for his current seventh-grade class, which he considered them as average to slightly below average. Therefore, he employs a more traditional teaching style with an emphasis on content explanation and practice question solving [KoL; adapting to students’ learning styles with ICT]. This adaptation reflects his awareness of his students’ learning characteristics and his ability to adjust his teaching strategies accordingly. Additionally, Asaf’s recognition of the need for less multiple-choice test-solving aligns with his formative assessment practices [KoA; in-class formative assessment] as he seeks to create a learning environment that caters to his students’ needs and enhances their comprehension of the subject matter. This demonstrates that Asaf’s understanding of his students’ learning styles (KoL) informs his approach to in-class formative assessment.

Furthermore, when describing the interplay between his awareness of students’

learning difficulties with ICT and out-class formative assessment strategies, Asaf underscores the importance of understanding his students' challenges during technology-integrated teaching. He explains that he gains insights into their learning difficulties when they engage with online assignments. Asaf elaborates this as *"Sometimes, I can clearly understand how much of the homework or tests I send through EBA they have completed by checking. It provides us with a question-by-question report, and I can quickly and clearly see where they struggled."* This statement illustrates how Asaf's awareness of students' learning difficulties with ICT [KoL] informs his use of out-class formative assessment tools [KoA], allowing him to identify specific areas where students need additional support and adapt his teaching accordingly.

In summary, Asaf demonstrates a dynamic interplay between his awareness of his students' learning needs, including their learning difficulties and diverse learning styles, and his assessment strategies. He effectively employs ICT-based motivational strategies to engage his students and adapts his assessment practices to align with their unique characteristics. This mutual interaction enhances the overall learning experience, creating an engaging and adaptive environment that caters to individual needs, boosts students' confidence, and addresses their learning difficulties effectively. In terms of the number of these interactions between KoL and KoA, a total of three interactions were seen in Asaf's data.

4.2.1.10. The Interaction between KoL and KoSC

As operationally defined, KoL-KoSC interplay involves strategically leveraging technology to diagnose students' learning difficulties, misconceptions, learning styles, background knowledge, and motivational needs, thereby enhancing their understanding by considering the alignment and appropriateness of subject content delivered with ICT. However, it is worth noting that obtaining data on these components can be challenging due to their complex nature. Based on the analysis of both observation and interview data of Asaf, there were no clear instances or indications of an interplay between his KoL and KoSC.

4.2.1.11. The TPACK-P Map of Asaf

The interactions among each TPACK-P component that emerged through the in-depth analysis were illustrated in the TPACK-P map (Figure 18). The creation of this map was elaborated on in the methodology chapter in detail. Based on the findings from Asaf's data, the following highlights were identified from his TPACK-P map:

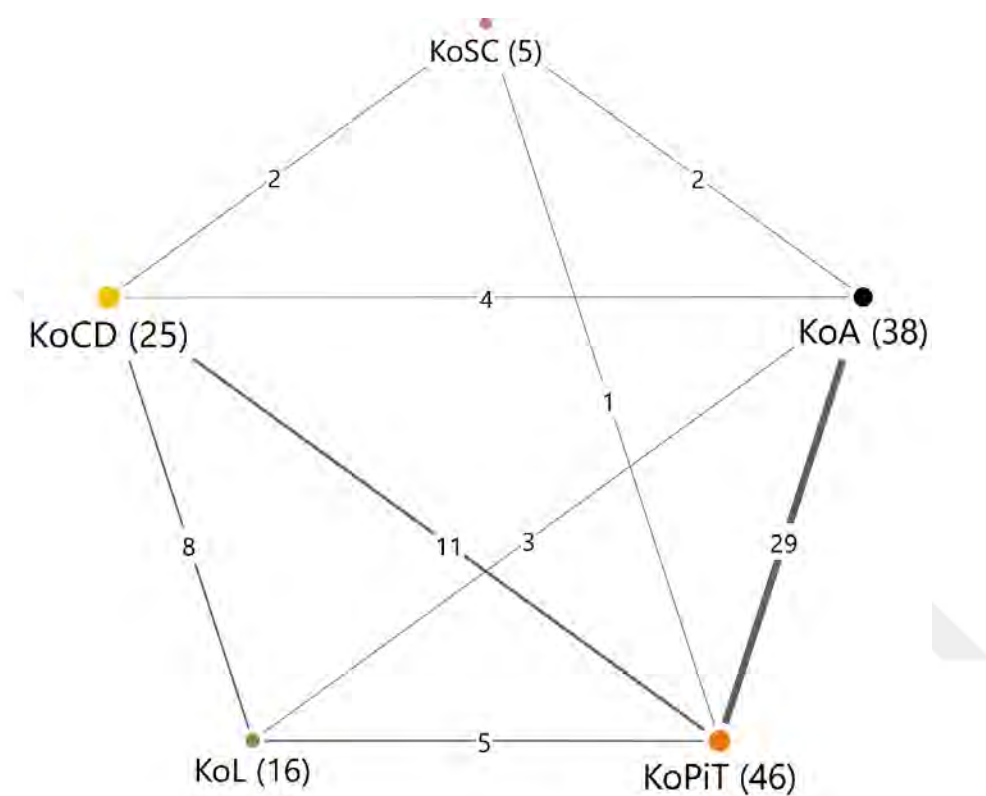


Figure 18. Asaf's TPACK-P map

- Since thicker lines indicate a higher frequency of interactions while thinner lines represent fewer interactions, it is clear that the interplay between KOA and KoPiT is very strong. This shows Asaf's assessment practices is highly integrated with especially his guidance on ICT use for students.
- Although there is interplay between Koa-KoSC, KoPiT-KoSC, KoCD- KoSC, KoL-KoA, And KoCD-Koa, these interplays do not seem to be strong, suggesting Asaf's limited integration or influence between these components.
- There is no clear instances or indications of an interplay between his KoL- KoSC interplay, indicating a lack of connection between Asaf's understanding of

students' learning needs and his adaptation of subject content delivery with ICT.

- The highest interactions revolve around the KoPiT component, portraying that Asaf's TPACK-P is mostly focused on his ICT-related challenges and management as well as ICT guidance. This suggests that Asaf's practices in teaching with ICT are central to his TPACK-P.

4.2.2. Case 2: Bora

In this section, a detailed analysis of the interplay among TPACK-P components in Bora's case was presented by considering ten potential interactions between these components. Each interaction was explored to provide insights into the nature of Bora's TPACK-P and how these components inform each other.

4.2.2.1. The Interaction between KoCD and KoA

The interplay between KoCD and KoA involves strategically integrating technology into science lessons through the selection of ICT representations and teaching techniques aligned with curriculum objectives. When examining Bora's TPACK episodes with the related codes under the category of KoCD and KoA, evidence of KoCD-KoA interplay is evident.

In one of Bora's classes (Observation of Bora's 7th class session), it is evident that the interplay between KoCD and KoA is prevalent. After discussing energy conversions, Bora brought up the subject of energy transformations and aimed to gauge his students' grasp of energy conservation. He threw a question to the students, wondering if they thought it was possible to figure out the energy of a tile falling from a certain height based on its starting energy and the height of the fall. Since the students remained silent, Bora realized they might not fully comprehend the concept. Then, he used the Antropi Teach software and started with a blank page on the smart board. He drew a situation where a ball with 100J of energy was falling from a height of 2m. He asked the students what kind of energy the ball would have when it got to a height of 1m. According to these observational data, Bora engaged the students in an in-class formative assessment activity [KoA], utilizing the 'Antropy teach' application [KoCD, drawing]. This interactive drawing activity allowed him to gauge the students' grasp

of the concept and adapt the instruction accordingly and making it a clear example of in-class formative assessment. Thus, KoCD informed KoA as Bora's curriculum design choices shaped the assessment strategies employed in the classroom in this example.

Likewise, Bora's utilization of ICT representations helps his assessment purposes. For instance, Bora introduced a new animation to the students (Observation of Bora's 7th class session), depicting two children jumping on a trampoline. Bora paused the animation and asked the students what type of energy the children possessed during the jumps. After receiving the students' responses, he conducted a voting activity in the class to determine how many students provided each answer. By doing so, Bora aimed to assess whether the majority of the students understood the concept of energy during the trampoline jumps. In this observation, it is evident that there is an interaction between KoCD and KoA. Bora's use of the animation [KoCD; animation] informed the in-class formative assessment activity [KoA; in-class formative assessment], where he assessed the students' understanding of the concept by using the animation as a visual aid and engaging them in the voting activity. Although the interaction between KoCD and KoA may not be as technology-intensive as in some other examples, Bora's incorporation of the animation as a tool for formative assessment still demonstrates the interplay between these two components in enhancing the learning experience in the classroom.

The interview data also indicates KoCD-KoA interactions in Bora's statements. According to him,

... I turn to z-books for the students. They already have the reference books, and I also have almost all the students' books in z-format, which I download to my computer. For instance, during courses, students sometimes bring me questions they couldn't solve. They say, 'Teacher, I couldn't solve this question.' Normally, I should solve it using the book they showed me, but other students wouldn't benefit from that, as they can't see it. So, I immediately open the relevant z-book, and all the students can see how I solved the question. This is a useful technique.

For instance, Bora mentions using z-books [KoCD; digital textbook/enriched e-books] as a valuable resource in the classroom. He explained that he downloads various z-books his computer. These digital versions of the students' textbooks become useful

when a student approaches him with a challenging question. Bora can quickly access the relevant z-book and show the solution to the whole class. This process serves as an in-class formative assessment activity [KoA], where he utilizes the digital resources to provide immediate feedback and demonstrate problem-solving techniques to all students. Bora's practice of using z-books as an archive of digital resources enhances the interaction between KoCD and KoA because he leverages the technology to support formative assessment practices and create a beneficial learning experience for all students by making the materials accessible to the entire class.

Similarly, the assessment strategies for formative assessment Bora used was influenced his knowledge on science program goals. Although Bora underlines the lack of time leads to low use of some assessment tools, he still tries to use them in the class. In his own words, *"Now, if you look at our curriculum program, the time is barely enough to cover the topics. So, the practice of solving questions from the z-books, as I mentioned earlier, doesn't get much time during regular classes."* Accordingly, Bora acknowledges that the standard curriculum time is barely sufficient to cover all the topics thoroughly but not solving many exercise questions from the z-books [KoCD, digital textbooks/enriched e-books] as in-class formative assessments [KoA]. This practice aligns with science program goals aiming to provide targeted support and address students' individual needs through in-class formative assessment strategies using the Z books. Thus, Bora's KoCD informs the implementation of KoA for a more effective and personalized learning experience.

Additionally, Bora also showed his awareness on the use of digital assessment tools in class for grading. That is, he mentions there are legal restrictions on using digital assessments, and they can only be utilized for in-class performance evaluations [KoA; ICT-based assessment awareness]. However, the Bora also points out that students may face accessibility issues with digital assignments or tests, for example, unavailability to access to digital devices or the internet by students [KoCD; ICT access]. This shows how the consideration of ICT-based assessment methods is influenced by the availability and access to digital resources for both the teacher and the students.

In summary, data presents the interactions between KoCD and KoA in Bora's teaching

practices. These interactions highlight how KoCD shapes the implementation of KoA in Bora's teaching practices, resulting in an enhanced and personalized learning experience. Through the analysis of the data, the number of these interplays was counted as a total of eleven interplays. The data from Bora's teaching practices demonstrated a dynamic interplay between KoCD and KoA, where each component informed and influenced the other.

4.2.2.2. The Interaction between KoCD and KoPiT

The evident interplay between KoCD and KoPiT showcases the teacher's guidance and engagement in ICT-infused learning designed with ICT-based representations, teaching strategies, and learning tasks, all tailored to the science curriculum. When Bora's TPACK episodes were examined, evidence of KoCD-KoPiT interplay became evident.

Based on the data gathered from the observation of Bora's teaching, there was only one evidence showing KoCD-KoPiT interplay. During teaching the direction of gravity (Observation of Bora's 2nd class session), Bora opened an animation where an airplane flying around the Earth was seen. He asked the class, 'Who could show the direction of the force of gravity?' When one of the students volunteered by raising her hand, Bora told her to open the drawing tool on the smart board to draw on the screen. Then, Bora approved and continued with the explanation. Based on these observations, it is evident that Bora effectively integrates KoPiT by involving students in the learning process using ICT [KoPiT; encouraging student use of ICT]. However, the limited student interaction during the explanation indicates a more teacher-centered approach [KoCD; guided lecturing]. Nevertheless, Bora acknowledges the student's contribution and continues with the explanation. Thus, Bora's curriculum design choices play a role in determining how and when students interact with ICT tools during the lesson, aligning with his overall teaching objectives and the integration of technology in the classroom.

On the other hand, interview data presents more interplay between KoCD and KoPiT for Bora. For instance, Bora discusses the using ICT tools helps him to spend less time and energy. In his own words,

... so, I use this program called Openboard and usually I write on it, or sometimes I use Antropy program. Openboard has other features too like drawing graphs. For example, speed-time graphs or distance-time graphs. You can divide the board into sections, draw graphs, it's actually a very handy program. You can use its different features. Like if we want to make changes to a question, it actually has many options. You select the question, transfer it to a different page, and make edits there. You don't have to draw everything all over again, it's really convenient. You can also save what you write, for instance. And there are special things for drawing graphs too.

Bora use such software to facilitate his curriculum design by utilizing Openboard, for example, to write and draw on the board, and even create graphs like speed-time and distance-time graphs with ease [KoCD; drawing]. Moreover, he appreciates the software's feature to save the work, which helps him save time and effort [KoPiT; saving time and effort]. In other words, he mentioned how these programs have features that make drawing graphs and shapes easier, and they allow him to save and reuse his work, which ultimately enhances his teaching process. Thus, Bora's knowledge on instructional management (KoPiT) on this situation influenced and shaped his curriculum design choices (KoCD) to incorporate ICT representations effectively in his teaching practices.

Another example of KoCD-KoPiT interplay is related to how Bora utilize ICT representations to effectively manage class time. In his teaching practice, Bora demonstrates a skillful incorporation of technology, leveraging various ICT tools and resources to create an enriched learning experience for his students. He utilizes platforms such as MORPA and EBA, and mentions using digital textbooks, enriched e-books, and digital lecture notes. Bora shares his approach to modifying questions from official resources, stating, *"The Ministry publishes sample questions... I take every relevant topic from them and create monthly PDFs."* This exemplifies his use of digital materials for the curriculum design [KoCD; digital textbook/enriched e-book]. Additionally, Bora emphasizes the efficiency of using digital resources in class, stating, *"Opening [the digital version] is essential during class. In the past, we used to show the page and ask students to look at the question, but now, I think it's more efficient to open it on the board, and they see it from there."* From these statements, the interplay between KoPiT and KoCD is clearly formed because Bora successfully optimizes the learning process by using technology to facilitate access to content. Moreover, Bora's practice of creating a digital archive of sample questions (z-books)

points to his intent to save time and effort for himself and his students [KoPiT; saving time and effort]. Thus, Bora's strategic combination of KoCD and KoPiT highlights the effectiveness of integrating ICT tools into his curriculum so that the overall learning experience and promoting efficient use of resources is accomplished by him. The direction of the interplay is from KoPiT to KoCD in these examples.

In summary, the data indicates Bora's two-way interactions between KoCD and KoPiT components. He is able to integrate technology into his teaching practice, leveraging various ICT tools like MORPA and EBA, digital textbooks, and z-books. His use of digital resources and efficient methods, such as creating monthly PDFs and saving time through digital graph drawing, demonstrates how his knowledge of practical teaching informs his curriculum design choices. The interplay between KoPiT and KoCD is evident, as Bora strategically combines technology with his teaching approach to create an engaging and time-saving learning experience. In terms of the number of these interactions, a total of five interactions were seen between KoCD and KoPiT components, which are considered as two-way interactions.

4.2.2.3. The Interaction between KoCD and KoL

The interplay between KoCD and KoL involves considering students' cognitive development, learning difficulties, and preferences when designing ICT-based science classes in alignment with the science curriculum. Upon analyzing TPACK episodes and codes under the categories of KoCD and KoL, multiple instances reflecting the KoCD-KoL interplay were observed in Bora's data.

In terms of Bora's interplays between KoCD and KoL in his teaching practices, limited evidence was gathered from the observations. To illustrate, Bora recalls conducting controlled experiments to his students while he solves exercise questions related to kinetic energy and mass relationship on the smart board (Observation of Bora's 5th class session). When he notices the next question on the screen is related to controlled experiment, then he first checked students' background knowledge using ICT by asking if they remembered certain concepts from the fifth grade [KoL; checking students' background knowledge using ICT]. The students seemed not to recall. To address this, Bora created a new blank page on the smart board and verbally defined the concepts first to refresh their memory [KoCD; using science process skills]. Then,

he was simultaneously explained and drew a small table on the screen and wrote the short definitions of variables to help students grasp the information better as illustrated in Figure 19. Thus, Bora's utilization of ICT tools to check students' background knowledge (KoL) influences his decision to use science process skills (KoCD) to reinforce their understanding.

Independent variable	The one that changes depending on the change I made
Dependent variable	The one that I changed directly
Controlled variable	The ones that are held constant can affect the dependent variable

Figure 19. Representation of the table that Bora drew on the smart board to explain types of variables

There is more evidence for KoCD-KoL interplay in Bora's interview statements. In line with observation data, Bora highlights how he gauges his students' background knowledge through ICT tools and varies his instructional approach as follows:

In the beginning of the unit, I measure the students' readiness level. When assessing their readiness level, I ask them some questions. While asking these questions, I can show various visuals, display images on the board, or even read a story, and then I measure the students' readiness level by asking questions based on these materials. (...) Later on, I deepen the topic by introducing various visuals, including animations, and proceed with the lesson in this manner.

Bora states that he starts his lesson by assessing his students' readiness levels by asking various questions and showing visual aids like images and stories. This process helps gauge students' background knowledge [KoL; checking students' background knowledge using ICT]. By understanding what his students already know and their interests, he gains insights into their prior knowledge and learning needs. This information, in turn, informs his instructional decisions and content selection [KoCD]. Then, Bora enhances curiosity by asking intriguing questions related to the upcoming topic. As he continues to ask questions, the students' interest in the subject grows. Subsequently, he deepens the understanding of the topic by using various visuals, such as animations, and delves into the subject matter. Evidently, these actions reflect a more teacher-centered approach while also incorporating student-centered elements, which implies adapting a guided lecturing [KoCD] teaching method. As Bora uses ICT

tools to assess his students' background knowledge and interests [KoL; checking students' background knowledge using ICT], he gains valuable insights into their learning needs and prior experiences. This understanding influences his decisions regarding the use of various teaching methods and techniques (KoCD). Thus, a reciprocal influence between KoCD and KoL was seen because Bora adapts students' instructional approach based on students' prior knowledge and interest to effectively convey the subject matter.

Similarly, Bora states that he is quite aware how he adapts his design according to the background level of his students. To illustrate, he describes this in the following statements:

On the other hand, in classes with high levels of achievement, I reduce the amount of direct instruction and focus more on solving exercise questions. I can understand their situation by observing their performance and class participation, sometimes through solving exercise questions on the smart board during our initial lesson.

In Bora's teaching approach, the interplay between KoCD and KoL is evident when he adapts his instructional methods based on students' level of achievement. For instance, in classes with high-achieving students, he reduces the amount of direct instruction and emphasizes solving exercise questions. Bora uses ICT tools to check students' background knowledge and performance through various means, such as solving questions on the smart board and observing their participation in the lessons. By doing so, he gains insights into their achievement levels [KoL; checking students' background knowledge using ICT]. Subsequently, he adapts his teaching methods, preferring solving exercise questions that suit their higher level of achievement [KoCD; level of achievement]. This reciprocal interplay is evident as Bora's knowledge of students' readiness and achievement levels (KoL) informs his decision to adapt his instructional methods, incorporating more problem-solving tasks (KoCD). Simultaneously, the choice of use of solving exercise questions on the smart board (KoCD) allows him to engage students effectively and assess their understanding and level of achievement (KoL).

In summary, Bora's teaching approach reflects a dynamic interplay between KoCD and KoL. Through his use of ICT tools, Bora effectively checks students' background

knowledge and adapts his instructional methods accordingly. He gauges students' readiness levels by asking questions and using visual aids to understand their prior knowledge and learning needs. This information informs his decisions on content selection and instructional strategies. This reciprocal interplay between KoCD and KoL allows Bora to effectively cater to his students' background knowledge, interests, and achievement levels, leading to a more student-centered and engaging learning experience. In terms of the number of these interactions between KoCD and KOL, a total of six interactions were seen, which are considered as two-way interactions.

4.2.2.4. The Interaction between KoCD and KoSC

The interaction between KoCD and KoSC involves a strategic selection of ICT elements aligned with science curriculum objectives. Upon analyzing Bora's TPACK episodes associated with the specific codes within KoCD and KoSC, the presence of this interplay between the two components became evident.

In one of Bora's classes (Observation of Bora's 2nd class session), he used the drawing tool on the smart board to enhance the understanding of the concept of gravity [KoSC; facilitating to understanding the content] after pausing the animation. Bora sketched two human figures on the polar and equatorial regions of the Earth and posed a question to the students. When he asks 'Whether both individuals would experience the same gravitational force at these points?', several students responded by raising their hands, and one student explained that the force of gravity would be greater at the polar region due to the Earth's flattened shape. Bora validated the student's response and proceeded to provide detailed explanations by himself, emphasizing the gravitational variation across different Earth regions [KoCD; guided lecturing]. This instructional approach including both the use of visuals and a small teacher-led interaction illustrates the interplay between Bora's knowledge of curriculum design and his efforts to facilitate content comprehension. The combined utilization of the drawing tool and guided lecturing contributes to students' enhanced understanding of the gravitational concept. Since it demonstrates how Bora strategically integrates various TPACK-P components to create an effective and engaging learning experience, it is reasonable to say that Bora's KoCD influences his approach to facilitating content comprehension (KoSC).

There is another example of how Bora's knowledge of curriculum design (KoCD) and his approach to facilitating content comprehension (KoSC) is evident through his instructional strategies. When solving exercise questions related to mass-velocity-kinetic energy topics on smart board (Observation of Bora's 5th class session), he realized that next question is related to using science process skills, specifically conducting controlled experiment. Bora initiated a short discussion by prompting students about their understanding of controlled experiments learned in fifth grade. When students remained silent, he used the smart board to create a new page and visually defines key concepts such as dependent and independent variables. By linking these concepts to relatable examples like plant growth and light intensity in circuits, Bora not only employed science process skills on the smart board [KoCD; using science process skills] but also employs a strategy that enhances students' understanding of the content of the questions [KoSC; facilitating to understanding the content]. His choice to integrate these instructional elements aligns with his broader curriculum design knowledge [KoCD], as he effectively structured the learning experience to incorporate both the use of science process skills and visual aids. Thus, Bora's expertise in curriculum design (KoCD) informs his instructional approach in facilitating content comprehension in exercise questions (KoSC).

In line with these observations, there are further evidence for KoCD-KoSC interplay in Bora's interview data. He states that he takes into consideration his students' demographic characteristics when designing the class because he thinks they grasp better understanding of the concepts if design is compatible with students' needs. He illustrates this as follows:

There are classes where Syrian students are in the majority, and there are classes with more individual differences. I take this into consideration. For instance, in a class where there are children who have difficulty understanding Turkish, I don't solve questions from the z-book because they cannot answer questions that involve reading comprehension and interpretation. Or in classes with a lot of heavy Turkish content, I reduce the content. Instead, I choose content that is rich in visuals, dominated by animations and videos.

Accordingly, Bora understands that the diversity in his class composition such as many Syrian students and varying language abilities, influences his curriculum design approach [KoCD; demographic structure]. In other words, Bora strategically minimizes the inclusion of content with dense Turkish narratives and textual

components. Instead, he chooses for content rich in visual elements, animations, and videos [KoSC; paying attention to content-ICT tool appropriateness]. This choice aligns with his curriculum design knowledge (KoCD) as it shows his skill in adjusting learning materials for his diverse student population. Thus, Bora's curriculum design choices are informed by the demographic structure of his class, where he effectively leverages ICT tools to create a more accessible and inclusive learning environment.

In summary, the interplay between Bora's KoCD and KoSC is evident through both observations and interview. His KoCD guides thoughtful curriculum design due to considering demographic factors like diverse language proficiency. This helps to the creation of customized content enriched with visual elements aligning with facilitating content understanding. Further, Bora integrates guided lecturing and science process skills such as controlled experiments to enhance comprehension the topics. These curriculum design choices align with his content delivery strategies result in an effective and tailored approach to science education that enhances students' grasp of subject content. In terms of the number of these interactions between KoCD and KoSC, a total of eleven interactions were seen, which are considered as two-way interactions.

4.2.2.5. The Interaction between KoPiT and KoA

The interplay between KoPiT and KoA involves teachers' expertise in addressing ICT challenges, managing instruction to meet student needs, and guiding effective technology use in science assessments. When examined Bora's TPACK episodes including codes under the categories of KoPiT and KoA, there are several evidence reflecting KoPiT-KoA interplay.

Similar to Asaf, the evidence for KoPiT-KoA interplay for Bora was mostly observed in his in-class formative assessment efforts and his guidance for ICT. More specifically, Bora encourages his students to actively utilize ICT tools when he presents exercise questions in the class. For example, Bora encouraged student participation in using ICT tools during an in-class formative assessment activity (Observation of Bora's 9th class session). He initiated the activity by suggesting, 'Let's solve a few questions related to these topics.' Bora used an online platform (EBA) to present the exercises. The first question required students to fill in the blanks. As

students took turns to answer, Bora instructed them to drag and drop the correct answers from the provided options into the gaps within the statements. These questions were related to concepts such as air resistance, the relationship between speed and friction in water, and water resistance. Based on this observation, it is evident that there is an interaction between Bora's encouragement of students' ICT use [KoPiT; encouraging student use of ICT] and his utilization of fill-in-the-blank questions in the class [KoA; in-class formative assessment]. This illustrates how Bora's facilitation of ICT-enhanced formative assessments contributes to his KoPiT component by actively guiding students in the effective use of technology for learning.

Bora's own statements also indicate how much importance he attaches to students' active participation in in-class formative assessment processes [KoA]. In his own words, Bora states, *"In all my classes, when I assess students, I call on them one by one [to the smart board]. All my students have spoken at least once in class."* Bora recognizes how his students understand the concepts. He underlines that he can assess his teaching's efficiency by actively engaging with his students. Bora reaches these conclusions by actively encouraging his students to participate in class activities where ICT tools are employed [KoPiT; encouraging student use of ICT]. As he mentions,

I give every student the right to speak, I make sure to put everyone on the board at least once a week. Then I can observe the level of their learning from their answers and sometimes even from their eyes.

Accordingly, it is evident that Bora adeptly utilizes in-class formative assessment tools not only to enhance students' comprehension but also to self-assess the effectiveness of his teaching. This implies that his expertise in assessment practices (KoA) informs and enhances his instructional strategies involving technology use (KoPiT).

Furthermore, the interplay between KoPiT and KoA is also evidenced from Bora's statements, especially concerning in-class formative assessment and the advantages of using ICT. Bora shares his approach to saving time and effort in preparing materials for his students [KoPiT]. He mentions that the Ministry provides sample questions, which he compiles into monthly PDF files, focusing on topics relevant to each subject. Notably, he regularly updates these materials with new questions and solves them himself, including previously administered questions. These questions take precedence in his assessments [KoA; in-class formative assessment]. Bora explains

this as follows:

Our Ministry publishes sample questions. I compile monthly PDFs containing questions related to each topic from these materials. Of course, I update them every year as new questions are released, and I make sure to solve them, including sample questions and those that have appeared in previous exams. These are the questions I prioritize during evaluations. After completing these, I turn to the Z-books. Students usually have their own reference books, and I have the digital versions of almost all the books that students commonly use. For instance, during courses, students often bring me questions they couldn't solve, saying, 'Teacher, I couldn't solve this question.' Normally, I should solve it from the textbook they have shown me. Otherwise, other students wouldn't benefit, and they wouldn't see it. So, I say, 'Let's open it up right away, which book is this from?' I open the Z-book, and all the students can see which question it is and how I solve it. This is a useful technique. Having a library of Z-books is also an advantage. There are digital versions of books from almost all publishers available. Teachers can use them for free, and as I mentioned, I have archived them. When a student brings a question, we can instantly open its digital example.

Furthermore, Bora discusses his use of z-books and how they offer an advantage for both him and his students. He downloads these digital textbooks, which correspond to the physical textbooks used by his students. When a student encounters a challenging question, Bora can instantly access the digital version of the specific textbook, allowing all students to witness how he solves the problem [KoPiT; ICT advantages/disadvantages]. This approach not only saves time but also leverages ICT to provide a deeper understanding of problem-solving strategies to all students. Thus, Bora's KoA informs his KoPiT by optimizing the assessment preparation process and efficiently utilizing digital resources to support his teaching. The integration of ICT tools and resources not only facilitates Bora's instructional management but also enriches students' learning experiences. This interaction underscores the value of leveraging ICT to enhance the interplay between KoA and KoPiT, benefiting both teachers and students.

Besides, Bora's statements shed light on the dynamic interplay between his KoA and KoPiT. Bora's approach to assessment reflects his awareness of both the advantages and disadvantages of ICT-based assessments. By stressing "*Once it is technology-based, it becomes much faster to see the assessment results.*", he emphasizes the speed of obtaining assessment results when assessments are technology-based. However, Bora highlights that technology-driven assessments enable teachers to quickly access

and review assessment results so that it makes the process more efficient [KoPiT; ICT advantages/disadvantages]. In his own words, *“When assessments are conducted on a topic/objective basis digitally, it is possible to identify students’ weaknesses. Otherwise, we interpret it ourselves, and how objective that is can be debated.”* Accordingly, he mentions that digital assessments facilitate the analysis of student performance, allowing teachers to identify specific areas where students may be struggling and the learning objectives they need to focus on. This analytical capability helps discovering students’ learning deficiencies more effectively than traditional assessment methods [KoA; awareness of advantages and disadvantages of ICT-based assessment]. Thus, Bora’s insights underscore how his awareness of ICT advantages and disadvantages informs his instructional practices to enhance the efficiency of assessment processes and enabling more objective evaluations of student performance. In other words, his awareness of ICT-based assessment advantages and disadvantages enhances the efficiency of assessment processes and enables more objective evaluations of student performance.

In summary, Bora’s teaching practices exhibit a dynamic interplay between KoPiT and KoA. Along with his effective management of digital resources, his active encouragement of ICT use in assessments showcases how KoA informs KoPiT. Bora’s awareness of ICT-based assessment’s advantages and disadvantages further enhances his instructional practices, which leads to more efficient assessments and objective evaluations of student performance. In terms of the number of these interactions between KoPiT and KoA, a total of eleven interactions were seen in Bora’s data.

4.2.2.6. The Interaction between KoPiT and KoL

Since there were limitations in gathering comprehensive evidence through observation alone, a limited amount of evidence was obtained only from the interview to explain KoPiT-KoL interplay. Based on the Bora’s interview data, there was only one piece of evidence for KoPiT-KoL interplay.

The interplay between Bora’s KoPiT and KoL is evident in his teaching approach according to his statement in the interview. Bora emphasizes that concretizing lessons during class significantly facilitates learning, with the most significant advantage being enhanced comprehension. He explains this as follows:

Concretizing lessons during class makes learning easier. This is the biggest advantage. ... When we use ICT tools, our performance is higher. Especially with Syrian students, I noticed that they understand lessons better when explained using technology. For them, seeing and hearing visual examples there contributes significantly to their understanding and learning, beyond my verbal explanations.

Accordingly, Bora underlines the use of ICT tools improves their performance because he particularly noticed in his Syrian students. He realizes that they better understand lessons explained using technological resources. For such students, visual examples that they can both see and hear instead of verbal explanations contribute significantly to their comprehension and learning [KoL; adapting to students' learning styles with ICT], and subsequently help him to achieve target learning goals [KoPiT; achieving target learning goals]. Thus, Bora's adaptation to students' learning styles with ICT (KoL) informs the achievement of desired learning outcomes (KoPiT), highlighting the interconnectedness of these components and their role in enhancing the learning process for students with diverse needs or backgrounds. In terms of the number of these interactions between KoPiT and KoL, only one interaction was seen.

4.2.2.7. The Interaction between KoPiT and KoSC

The interplay between KoPiT and KoSC integrates pedagogical expertise, effective ICT use, and strategies for delivering science content while focusing on harmonious content-ICT integration and enhancing student comprehension. However, due to limitations in gathering comprehensive evidence of KoSC through Bora's observation and interview data, only one piece of evidence was obtained to explain this interplay.

Bora's interview data reveals a clear interplay between his KoPiT and KoSC. Bora asserts that the incorporation of technology into all of his lessons significantly eases the process of comprehending abstract concepts since it provides visual aids such as videos and images. In his own words, Bora states,

Using technology in all my classes makes my job easier. Because when I talk about a concept, it remains abstract for the students. However, when they watch a video on the smart board or look at an image, it clarifies their understanding. (...) In the past, we used to rely on memorization. Students would memorize without understanding. But now, when they watch an animation, they say, 'I have watched it! This is how it works.' This makes their learning more permanent.

According to him, animations, videos, or images aid students in grasping concepts more effectively, aligning with his goal of achieving target learning goals [KoPiT]. In contrast to the past, where memorization was the primary method for teaching, Bora's adoption of technology now encourages students not only to remember but also to comprehend the subject matter [KoSC; facilitating to understanding the content]. Therefore, Bora's use of technology to achieve target learning goals (KoPiT) informs and enhances his facilitation of students' understanding of complex subject content (KoSC). In terms of the number of these interactions between KoPiT and KoSC, only one interaction was seen.

4.2.2.8. The Interaction between KoA and KoSC

The KoA-KoSC interplay involves using formative assessment strategies with ICT tools to align subject content delivery effectively. This ensures student understanding and enhances clarity in learning. When examined Bora's TPACK episodes including codes under the categories of KoA and KoSC, there is only one evidence reflecting KoA-KoSC interplay.

In one of the observed classes of Bora (Observation of Bora's 4th class session), the interplay between Bora's KoA and his KoSC is evident. Accordingly, Bora takes deliberate actions to facilitate his students' understanding of complex content related to kinetic energy. During that class, he provided a clear explanation to prevent students from forgetting a crucial concept which is kinetic energy depends on an object's velocity and mass. Meanwhile, he urged his students to remember this information while solving similar questions. To understand better, Bora told them to practice some exercise questions. Subsequently, he opened relevant questions on EBA to demonstrate to his students [KoA; in-class formative assessment]. One of these questions involved interpreting a table and ranking kinetic energies of objects X, Y, and Z based on their given mass and velocity. Bora allowed students time to think and then engages them by asking for a volunteer to answer. Then, the selected student correctly related kinetic energy to mass and velocity, which reflects an understanding that Bora has helped to foster [KoSC; facilitating to understanding the content]. Thus, Bora's use of in-class formative assessment becomes evident as he guides the student to consider both mass and velocity in their reasoning and encourages their active

participation in solving the question. This dynamic interplay ensures that Bora's content knowledge informs his assessment strategies, thereby enhancing comprehension and promoting active engagement among students. In terms of the number of these interactions between KoA and KoSC, only one interaction was seen.

4.2.2.9. The Interaction between KoL and KoA

The KoL-KoA interplay involves dynamically using ICT-based formative assessments to align with students' cognitive development, learning needs, and preferences, enhancing learning experiences within the ICT environment. When examined Bora's TPACK episodes including codes under the categories of KoL and KoA, there is only one piece of evidence in the observation data reflecting KoL-KoA interplay.

While Bora was presenting some exercise questions related to potential and kinetic energy on the smart board (Observation of Bora's 8th class session), it was observed that a clear interplay exists between his awareness of students' learning difficulties with ICT (KoL) and his in-class formative assessment strategies (KoA). When he presented a short-answer question that involves a straightforward calculation regarding the change in energy of an object with an initial energy of 8E as it moves. During this task, Bora engages in question-and-answer process to attempt to understand how his students approach the question. Subsequently, he realized that the students are having difficulty comprehending the question. In response, Bora first solved the question himself. Nonetheless, because the students still struggled to grasp the solution, he reiterated the process by elaborating his explanations. The second time he went through the solution, most students reflected that they understood this time. This dynamic interaction showcases how Bora's awareness of his students' learning difficulties with ICT (KoL) informs his in-class formative assessment practices. By actively engaging with his students through in-class formative assessment techniques [KoA], Bora gains valuable insights into their learning processes and challenges, thereby enhancing his awareness of students' learning difficulties [KoL]. As a result, he can precisely identify specific areas where students are struggling to understand the question. His proactive use of in-class formative assessment not only informs his teaching strategies but also enables him to address these identified challenges effectively. In terms of the number of these interactions between KoL and KoA, only

one interaction was seen.

4.2.2.10. The Interaction between KoL and KoSC

The KoL-KoSC interplay strategically uses technology to enhance student understanding by addressing their learning needs, but obtaining data on these components can be challenging due to their complexity. When examined Bora's TPACK episodes including codes under the categories of KoL and KoSC, there is limited number of evidence in the data reflecting KoL-KoSC interplay.

According to the observations of Bora's classes, a clear interplay between his KoL and KoSC. For example, during one of his lessons focused on science process skills and the relationship between kinetic energy and mass (Observation of Bora's 5th class session), Bora initiated an ICT-based exercise. As he presented the exercise questions, he noticed that the students were struggling to recall fundamental concepts related to controlled experiments, specifically the notions of independent and dependent variables [KoL; checking students' background knowledge using ICT]. Bora also told them they should have acquired this knowledge in their fifth-grade curriculum. In response to their lack of recall, he used ICT by opening a new page on the smart board to visually represent and define these concepts. Initially, he wrote down the three types of variables and verbally explained their meanings by exemplifying different context. For instance, he gave an example related to measuring a plant's growth concerning water amount to emphasize that the amount of water would be the independent variable. Later, he explained the term 'dependent variable' in the context of a circuit with two batteries, illustrating how the number of batteries would be the independent variable while the brightness of the bulb would be the dependent variable. These explanations and visual representations served to facilitate the students' understanding of the content [KoSC; facilitating understanding of the content]. Thus, Bora's ability to recognize the gaps in students' background knowledge using ICT (KoL) allowed him to adapt his teaching approach by employing the smart board to clarify and facilitate their understanding of the subject content (KoSC). Accordingly, Bora takes into consideration of his students' This dynamic interplay between KoL and KoSC demonstrates his effective use of technology to bridge knowledge gaps and enhance the students' comprehension of science concepts.

Furthermore, there is another evidence for KoL-KOSC interplay in Bora's observation data. During a class session (Observation of Bora's 7th class session), Bora brought up the subject of energy transformations and aimed to gauge his students' grasp of energy conservation. He threw a question to the students, wondering if they thought it was possible to figure out the energy of a tile falling from a certain height based on its starting energy and the height of the fall. The students did not respond, hinting they might not fully understand. Seeing their uncertainty, Bora chose to use visual aids to make the idea clearer. Recognizing the students' difficulty in understanding the question and their need for clarification [KoL; awareness of students' learning difficulties with ICT], Bora decided to employ ICT tools to visually represent the problem. To do so, he utilized the Antropy Teach application, opening a blank page where he presented questions related to a 2-meter fall of an object with 100 Joules of energy. This visual representation aimed to facilitate the students' understanding of the concept of energy conservation and engage them in active problem-solving [KoSC; facilitating understanding of the content]. This dynamic interplay between KoL and KoSC highlights Bora's effective use of technology to address students' learning difficulties and enhance their comprehension of scientific concepts. In this example, the direction of the interplay is from KoL to KoSC. Bora's awareness of the students' learning difficulties with ICT prompts him to use technology to facilitate their understanding of the content more effectively.

In line with this, Bora's interview data reveals a clear interplay between his KoL and KoSC, particularly focusing on paying attention to content-ICT tool appropriateness (KoSC) and checking students' background knowledge using ICT (KoL). He demonstrates his awareness of the importance of adapting his teaching methods to individual differences and specific needs of his students based on their individual backgrounds by stating *"For example, in a class where some children struggle to understand Turkish, I don't use questions from the z-book. This is because they can't do questions that involve reading comprehension and interpretation."* Accordingly, he considers the diversity of his classroom such as the presence students who struggle to comprehend Turkish, he avoids using the z-book and its comprehension-based questions since these students may not be able to tackle questions that involve reading, comprehension, and interpretation. Instead, he prefers content rich in visuals,

animations, and videos. Conversely, in higher-achieving classes, he reduces content that relies heavily on Turkish narration and places more emphasis on problem-solving. Bora's awareness of these situations allows him to adapt his teaching materials and approaches accordingly [KoSC; paying attention to content-ICT tool appropriateness]. Moreover, he elaborates that he gauges students' situations by observing their performance in early lessons with smart board-based questions as well as their overall success and participation in the class as he quotes *"I can understand their levels [of background knowledge] by observing them sometimes with the questions we solve on the smart board in our first lessons, and sometimes by observing their success and participation in the class."* Hence, his statement reveals his KoL as he demonstrates an awareness of the diverse levels of his students' background knowledge through observation of their engagement with smart board-based questions and their overall class performance [KoL; checking students' background knowledge using ICT]. This shows how Bora's KoL, which is marked by an awareness of students' diverse language skills and learning needs, informs his KoSC by guiding him how he selects what to teach and how to teach it effectively to meet those specific needs. Thus, this dynamic interplay between KoL and KoSC allows him to adapt his teaching effectively.

In summary, Bora's instructional practices demonstrate a clear and dynamic interplay between his KoL and KoSC. Bora effectively identifies students' deficiencies in fundamental scientific concepts such as independent and dependent variables by using ICT tools to address these gaps. Simultaneously, he enhances students' comprehension by visually representing and explaining these concepts. Bora's instructional decisions are well-informed by his awareness of individual student needs (KoL). This allows him to select appropriate content and teaching strategies. Overall, KoL-KoSC interplay highlights Bora's adept use of technology to tailor instruction, bridge knowledge gaps, and improve student engagement and learning outcomes. In terms of the number of these interactions between KoL and KoSC, a total of three interactions were seen in Bora's data.

4.2.2.11. The TPACK-P Map of Bora

The interactions among each TPACK-P component that emerged through the in-depth

analysis were illustrated in the TPACK-P map (Figure 20). The creation of this map was elaborated on in the methodology chapter in detail. Based on the findings from Bora's data, the following highlights were identified:

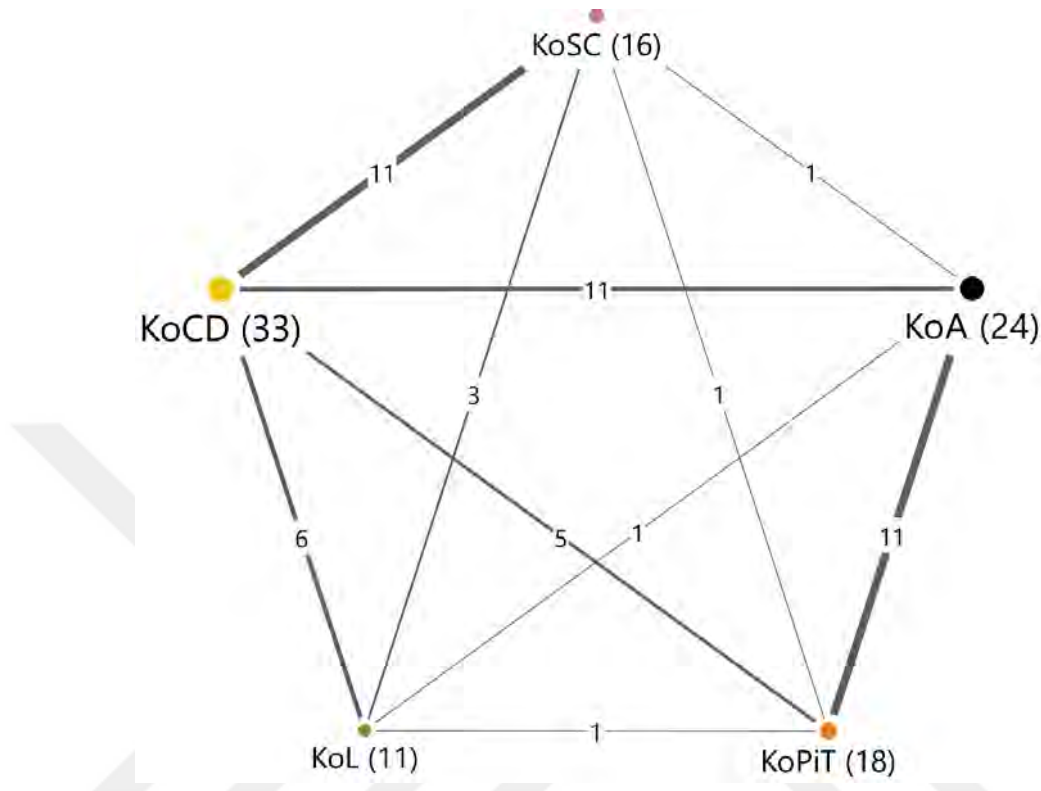


Figure 20. Bora's TPACK-P map

- The presence of thick lines connecting KoPiT-KoA, KoCD-KoA and KoCD-KoSC in Bora's TPACK-P map indicates the existence of strong interplays. These strong interplays suggest that not only his effective guidance and management skills in integration of technology in assessment processes, but also his adept planning and design skills shape during assessing students with ICT, as well as his skillful planning and designing for selection of appropriate science content delivered with ICT, play pivotal roles.
- Although there is interplay between KoPiT-KoSC, KoA-KoSC, KoL-KoSC, KoL-KoA, KoPiT-KoL, these interplays do not seem to be strong, suggesting Bora's limited integration or influence between these components.
- Bora's TPACK-P map contains all possible interactions between each component, revealing his comprehensive understanding of technology integration despite some of the interactions not being very strong. This

comprehensive connectivity underscores his ability to effectively leverage technology in science education.

- In Bora's TPACK-P map, the number of interplays between components varies, with some components having a close number of interactions, while KoCD stands out with the highest number of interactions. This prominence of KoCD in the interplays suggests its central role in shaping Bora's TPACK-P as other components also contribute with their respective interplays.

4.2.3. Case 3: Cenk

In this section, a detailed analysis of the interplay among TPACK-P components in Cenk's case was presented by considering ten potential interactions between these components. Each interaction was explored to provide insights into the nature of Cenk's TPACK-P and how these components inform each other.

4.2.3.1. The Interaction between KoCD and KoA

The interplay between KoCD and KoA involves strategically integrating technology into science lessons through the selection of ICT representations and teaching techniques aligned with curriculum objectives. When examined Cenk's TPACK episodes including codes under the categories of KoCD and KoA, there are several evidence reflecting KoCD-KoA interplay.

During the observation of a Cenk's class (Observation of Cenk's 12th class session), it was observed that Cenk considered his students' conditions in terms of their access to ICT at home. Before he assigned a design task, he checked whether all students have access to computers, smartphones, and the internet at their home [KoCD; ICT access]. Afterwards, he demonstrated how to use different platforms for the assignment, including Tinkercad and the 3D Modelling App. This brief demonstration of these platforms, Cenk encouraged students to engage in an assessment based on product development [KoA] where they are expected to design a vehicle to minimize air and/or water resistance. According to this observation, it is evident that Cenk's consideration of students' ICT access [KoCD] informs the assessment strategy [KoA] employed in the classroom.

Similarly, there is further interplay between KoCD and KoA when Cenk used ICT representations (Observation of Cenk's 12th class session). That is, Cenk was observed in using a USB flash drive to open a PDF document containing test questions [KoCD; digital lecture notes]. Cenk used an online random drawing website [KoA; in-class formative assessment] for determining the next student who will come to the smart board to solve the next question. This formative assessment activity engaged the students in solving the test questions and promotes active participation in the classroom. Similar to this, during the observation of Cenk's another class, he noticed that the class had a low response rate to some questions. Then, he decided to prompt to access the PDF summaries of the lessons stored in his flash drive [KoCD; digital lecture notes]. The summaries seemed to provide quick definitions and relationships of the concepts. Cenk used this resource as a formative assessment strategy to support the students' understanding by referring to the concept map and filling it together with the students [KoA; in-class formative assessment]. This approach helps him to address areas of difficulty and reinforce the concepts collaboratively. In both observations, Cenk's use of digital resources [KoCD] informs and enhances the in-class formative assessment practices [KoA] employed in the classroom.

Interview data of Cenk further supports to existence of KoCD-KoA interplay. For example, Cenk's statements below clearly illustrate how the interactions between KoCD and KoA during his teaching:

Other than that, sometimes there are expectations such as model drawing in the curriculum objectives. We talked to a colleague at school and thought it would be helpful to have a drawing done. We already expect those who have the means to participate in this activity. (...) As for myself, I assigned a design task related to model drawing in the final attainment of the unit, and after showing it in class, many students actively participated.

These statements of Cenk suggest that his awareness on curriculum targets related to model drawing in this topic. His collaborative discussion with another teacher [KoCD; peer cooperation] on assigning a drawing task in digital environment shows his personal approach on incorporating technology in the teaching process. According to these statements, Cenk's curriculum design choices (KoCD) incorporate model drawing expectations into the teaching approach. Moreover, the assignment of ICT-based assessment for product development (KoA) encourages considerable student

participation. Thus, the interplay between KoCD and KoA is evident as Cenk's choices in curriculum design shaped the assessment strategy employed in the classroom.

In summary, the analysis of TPACK episodes and observations of Cenk's classes reveal evidence of KoCD-KoA interplay in his teaching practices as his curriculum design informs and enhances the assessment strategies employed in the classroom. Through the analysis of the data, the number of these interplays was counted as a total of four interplays, which are only one-way interactions (from KoCD to KoA).

4.2.3.2. The Interaction between KoCD and KoPiT

The evident interplay between KoCD and KoPiT showcases the teacher's guidance and engagement in ICT-infused learning designed with ICT-based representations, teaching strategies, and learning tasks, all tailored to the science curriculum. When Cenk's TPACK episodes were examined, evidence of KoCD-KoPiT interplay became evident.

Based on the data gathered from the observations of Cenk's teaching and his interview, there are valuable insights showing KoCD-KoPiT interplay. For example, during the observed session of his teaching (Observation of Cenk's 3rd class session), Cenk effectively utilized multiple ICT tools to engage students in the learning process. By opening an e-experiment and presenting a question to explore the relationship between applied force and work done, he provided a hands-on and interactive learning experience. One significant observation was when Cenk invited a volunteer student to the board to respond to the question and encouraged them to test their hypothesis through observations. Additionally, Cenk used interactive buttons and prompts on the screen, such as the + button to apply a 10N force to the robot, allowing students to directly interact with the experiment. Furthermore, Cenk's intervention to have the student access the experiment report and the subsequent discussion about the importance of multiple observations demonstrated his understanding of the research process and the need for reliable data collection. The student's consistent response and unchanged hypothesis after observing the relationship between force and work confirmed the effectiveness of Cenk's instruction in supporting students' understanding and hypothesis testing. Cenk also emphasized the significance of multiple observations by prompting the student to perform a third observation with a

30N force. The session concluded with audio and written feedback confirming the validity of the hypothesis, and Cenk reiterated the experiment to ensure thorough comprehension among the entire class. Furthermore, he utilized the experiment report section to revisit the findings and explain the resulting conclusion, promoting further analysis and interpretation of the collected data. In this observation, Cenk utilizes the EBA platform to conduct a virtual experiment with the students. He sets up a simple experiment to explore the relationship between applied force and work done. The students interact with the experiment using + and – buttons [KoCD; virtual experimenting], and Cenk asks them questions about the observed relationship between force and work. The students make hypotheses, test them through observations, and record their findings, showcasing their utilization of science process skills [KoCD; using science process skills], while interacting with the virtual experiment on the screen [KoPiT; encouraging student use of ICT]. Cenk emphasizes the importance of making multiple observations to ensure reliable data collection. The students adjust the force and conduct further observations, confirming their initial hypothesis. The digital platform provides instant feedback, validating their conclusions. Cenk also guides the students to interpret the data, encouraging deeper understanding. The combination of hands-on experimentation and ICT integration enhances the learning experience, highlighting a successful interplay between KoCD and KoPiT in Cenk's teaching approach. Thus, the direction of interplay is from KoPiT to KoCD in this example.

Similar to this, Cenk was observed primarily guiding students' use of ICT by demonstrating its proper application to them. For example, an interactive experimental environment was displayed on the screen by Cenk (Observation of Cenk's 4th class session), which features a setup with two different masses of balls attached to a tripod stand and a box filled with soft sand where the balls could fall into. The experiment was designed to explore how the energy of the ball, which varied due to changes in mass and height, could be altered. Then, Cenk selected a student as a volunteer to conduct the experiment. Before starting the experiment, he explained to the student that they will complete the experiment in two stages. Then, the student increased the speed by changing the height from which the object was dropped and tracked the findings by touching the experiment report section. Before the experiment, the student

had chosen the hypothesis that speed is inversely proportional to kinetic energy. Initially, Cenk asked the student to make two observations without providing any comments. Later, when he asked the student ‘When you look at the findings, how does energy change as speed increases?’ the student thought for a moment and responded ‘Both have increased.’ Cenk then asked ‘So, do you think your hypothesis is correct?’ In return, the student said, ‘No, they should be directly proportional because both have increased’. After he had the student make the necessary observations on the screen and answer the questions, the relevant part of the experiment was completed. On this particular observation, it is evident that Cenk effectively integrates his KoPiT and KoCD during the experiment. Cenk selects a student as a volunteer and guides him through the experiment, demonstrates how to adjust the height to increase the speed and prompting him to record the findings in the experiment report section [KoPiT; guiding students to learn using ICT]. Cenk prompts the student to make multiple observations without providing direct feedback to encourage him to apply science process skills such as observing, recording data, testing hypothesis [KoCD; using science process skills]. After the student completes the experiment on the smart board [KoCD; virtual experimenting, KoPiT; making student use ICT], the student realizes that both speed and energy had increased, and decides to modify his hypothesis. Thus, Cenk’s approach in this observation demonstrates how he skillfully integrates KoPiT and KoCD. The direction of the interplay between KoCD and KoPiT is from KoPiT to KoCD because Cenk effectively integrates ICT into his teaching by guiding students in using ICT tools during the experiment.

In line with observation data, the interview with Cenk also shows evidence for KoCD-KoPiT interplay. Cenk illustrates how he use concept maps to facilitate students’ learning as well as their familiarness with ICT tools. In his own words,

Actually, I have some lessons where I draw concept maps, but I use them for starting the lesson or summarizing the lesson rather than grading. I use GitHub on my phone, I reflect it on the smart board. Children both see how I draw and learn. It seems clearer and more understandable.

Cenk mentions that he uses concept mapping in some of his lessons to start a new topic or to summarize the lesson. He utilizes GitHub on his phone and reflects it on the smart board. By demonstrating the process of drawing concept maps using GitHub and the smart board. [KoCD; drawing]. Cenk not only facilitates their understanding of the

subject matter but also equips them with the skill of creating concept maps themselves [KoPiT; guiding students to learn using ICT]. This hands-on experience empowers students to develop their own conceptual understanding and organize information in a visually structured manner. Thus, the direction of the interplay is from KoCD to KoPiT because Cenk's use of concept mapping and drawing with GitHub and the smart board informs and influences his approach of Guiding students to learn using ICT tools effectively. By demonstrating the process of drawing concept maps, Cenk not only facilitates students' understanding of the subject matter but also equips them with the skills to utilize ICT tools for learning purposes.

Another piece of evidence for KoCD-KoPiT interplay in Cenk's interview is related to his ICT-infused course design purpose. When asked about the importance of using ICT tools in the learning process, Cenk emphasized the importance of other educational target he holds as *"When I involve children in the lesson and when a child stands up and touches the screen, I give them both a sense of responsibility and the perception that 'I can do it,' and I find it to be very effective."* Based on these statements, it is evident that there is an interplay between KoCD and KoPiT in Cenk's teaching approach. By involving children in the lesson and encouraging them to interact with the screen, Cenk not only achieves his hidden program goal of fostering a sense of responsibility in the students [KoCD; hidden program goals] but also fosters their confidence and belief in their abilities [KoPiT; encouraging student use of ICT]. This approach of actively engaging students with ICT tools contributes to an effective and empowering learning experience in Cenk's classroom. Thus, the direction of interplay in this scenario is from KoPiT to KoCD. Cenk's emphasis on involving students in the lesson and encouraging them to interact with the screen using ICT tools enables him to achieve some of educational goals beyond science program goals.

In summary, there are clear evidence of KoCD-KoPiT interplay for Cenk. By engaging students with hands-on experiences and interactive learning, he fosters understanding and confidence. Moreover, integrating concept mapping and drawing with ICT tools enhances learning. The interplays are bidirectional where KoCD informs KoPiT and vice versa, which result in effective teaching and learning. The total number of the interplay was estimated as eight.

4.2.3.3. The Interaction between KoCD and KoL

The interplay between KoCD and KoL involves considering students' cognitive development, learning difficulties, and preferences when designing ICT-based science classes in alignment with the science curriculum. Based on the data gathered from observations of Cenk's classes and his interview, the analysis of TPACK episodes with codes from KoCD and KoL shows evidence reflecting KoCD-KoL interplay in the observations and interview of Cenk.

During the observation of Cenk's teaching (Observation of Cenk's 3rd class session), a clear interplay between KoCD and KoL was observed. Cenk started the lesson by accessing the EBA platform and utilizing animations related to the new topic. He reminded the students about the previous lesson's discussions on gravity, mass, and weight, as well as the misconception related to the mass-weight relationship. Through the use of animations, Cenk aimed to identify and address the students' misconception [KoL; identifying students' misconceptions using ICT]. To clarify the concept of 'work', Cenk presented an animation with various scenarios to highlight the necessity of force and displacement for work to occur [KoCD; animation]. He paused the animation and engaged the students in a discussion by asking them to identify examples of work in the manner of physics although he took a more teacher-centered approach [KoCD; guided lecturing]. This interactive approach allowed Cenk to further identify any potential misconceptions the students might have had regarding the concept of work [KoL; identifying students' misconceptions using ICT]. By utilizing ICT tools and interactive animations, Cenk effectively addressed students' misconceptions related to the mass-weight relationship and the concept of work. The interplay between KoCD and KoL is evident as Cenk's knowledge of students' misconceptions informed his decision to use animations and interactive discussions to reinforce their understanding and correct any misconceptions.

In line with this, Cenk's statements during the interview also support the interplay between KoCD and KoL. Cenk, by addressing the structure of science program as follows:

Since the topics are covered spirally, students can see them concretely in videos. Moreover, if there is any misconception, I can catch it from the answers they give

when I ask questions. And sometimes, when I give the opportunity to a student who wants to ask a question, I come across such situations.

Accordingly, Cenk's teaching approach exhibits an interplay between KoCD and KoL. Cenk utilizes videos to make the topics more concrete for students [KoCD; video]. This approach allows students to visualize the concepts covered in a spiral manner. Additionally, Cenk states that he can identify any misconceptions students may have through watching those videos or students' questions after watching them [KoL; identifying students' misconceptions using ICT]. By actively engaging with the students and giving them the opportunity to ask questions, Cenk gains valuable insights into their understanding and learning needs [KoL]. Therefore, KoCD informs KoL in this case, as Cenk's instructional methods and choices (KoCD) inform his understanding of students' comprehension levels and misconceptions (KoL).

Moreover, Cenk also mentions that he can adjust his instructional design choices based on his students' learning difficulties. When asked about determining students' learning difficulties using ICT, Cenk explains his online assessment tasks as follows:

I listen to the reasons of those who cannot or do not solve. Their access to IT tools is either non-existent or very limited. But for those who have access, their participation is great, and I feel that the assignments are achieving their purpose.

Cenk describes a clear interplay between KoCD and KoL in his teaching practices. He acknowledges that some students face difficulties due to limited or no access to ICT tools [KoL; awareness of students' learning difficulties with ICT]. To address these challenges, Cenk also states that *"If I notice gaps in their subject knowledge, we spend more time for this. I aid their learning by introducing new animations, videos, simulations, or experiments when possible."* Cenk incorporates various instructional strategies, including animations, videos, simulations, and interactive experiments [KoCD; animation; simulation; video; interactive experiment] to enhance students' learning experiences. At the same time, this demonstrates his recognition of the impact of ICT access on students' participation and learning outcomes when designing his class [KoCD; ICT access]. For students with limited access to technology, Cenk utilizes these interactive tools to reinforce their understanding. He also devotes additional time to problematic topics and introduces new interactive tools such as simulations or experiments [KoCD] to support their learning. This interplay between

KoCD and KoL enables Cenk to tailor his instructional approach based on students' learning difficulties and adapt his teaching methods to ensure effective learning outcomes. Thus, KoL informs KoCD in this case.

Another evidence for KoCD-KoL interplay for Cenk is related to how his awareness of motivational factors of students to engage the class shapes his instructional design. When asked about the motivation of his students when ICT-based class, Cenk states,

When I engage them with interactive activities on the smart board, the students become very enthusiastic because their participation increases. For instance, if three students raise their hands in response to a question I ask, when the same question is presented through a smart board application, ten to fifteen hands are raised. Perhaps the students are more motivated to interact with something beyond the monotonous teacher-student relationship. Additionally, getting up, touching the board, interacting with the computer to provide answers, and the satisfying ticks and sounds that appear when they give correct answers make them even happier.

Accordingly, Cenk's understanding of ICT-based motivational strategies for students becomes evident in his ability to engage students effectively through interactive activities on the smart board [KoL; recognizing ICT-based motivational strategies for students]. Alongside this, Cenk highlights the type of content he prefers to use during his classes, stating, "*So, I continue to use these platforms because of the students' satisfaction.*" It is clear that his students' satisfaction with his teaching methods motivates him to further enhance his instructional design by incorporating more interactive elements, such as animations, videos, and interactive experiments [KoCD; student satisfaction]. Moreover, students' interactions with technology, like touching the board and providing answers through the computer, significantly contribute to their satisfaction and motivation. As a result, Cenk's instructional decisions are influenced by his consideration of student satisfaction. This interplay between KoCD and KoL enables Cenk to tailor his teaching methods effectively to ensure students' enjoyment and successful learning outcomes.

In summary, Cenk's teaching approach reflects a dynamic interplay between KoCD and KoL. Through his use of animations, videos, and interactive discussions, Cenk identifies and addresses students' misconceptions. He adapts his instructional design based on students' learning difficulties, incorporating new tools like simulations or experiments. Moreover, Cenk's awareness of students' motivational factors informs

his instructional decisions. This interplay between KoCD and KoL enables Cenk to tailor his teaching approach effectively, fostering positive learning experiences and successful outcomes. The total number of interplays identified in the data was nine, which are two-way interactions between KoCD and KoL.

4.2.3.4. The Interaction between KoCD and KoSC

The interaction between KoCD and KoSC involves a strategic selection of ICT elements aligned with science curriculum objectives. Upon analyzing Cenk's TPACK episodes associated with the specific codes within KoCD and KoSC, the presence of this interplay between the two components became evident.

During the observed session of his teaching (Observation of Cenk's 3rd class session), Cenk opened an e-experiment [KoCD; virtual experimenting] and presenting a question to explore the relationship between applied force and work done. Cenk invited a volunteer student to the board to respond to the question and encouraged them to test their hypothesis through observations [KoCD; using science process skills]. After the session concluded with audio and written feedback confirming the validity of the hypothesis, Cenk reiterated the experiment to ensure thorough comprehension among the entire class. Additionally, he utilized the experiment report section to revisit the findings and explain the resulting conclusion to promote further analysis and interpretation of the collected data [KoSC; facilitating to understanding the content]. This instructional approach exemplifies the interplay between Cenk's KoCD and his approach to facilitating content comprehension (KoSC). Cenk's knowledge of curriculum design informs his approach to facilitating content comprehension.

In another class of Cenk, he was observed that he himself solved the first question on exercise question while students solved the rest. When asked to him the reason of this, he explains himself as *"I wanted to show the students how to approach and solve the questions in the test I provided because sometimes students may not know the solution method."* This suggests that Cenk recognizes that some students may not know how to approach and solve the questions in the test. To address this, he takes the initiative to demonstrate the solution method to the students before they attempt to solve the questions themselves. This approach involves lecturing [KoCD; lecturing] aims to

facilitate the students' understanding of the content by providing them with guidance on the problem-solving process [KoSC; facilitating to understanding the content]. Therefore, Cenk's decision to demonstrate how to approach and solve the test questions is driven by his desire to facilitate the students' understanding of the content. He uses lecturing as a means to achieve the goal of helping students comprehend the material better. Thus, his KoSC informs his KoCD.

During the interview with Cenk, there is one evidence displaying KoCD-KoSC interplay. Cenk believes all the subtopics of force and energy unit is suitable for using ICT but some topics require use of ICT inevitably. He illustrates this as follows:

It becomes more suitable for topics that are harder to show or demonstrate, especially abstract ones. For instance, atoms. It's not globally clear how to show atoms. Children struggle to understand things they can't see. But when you explain with visuals, especially animations, they find it more comprehensible. The three subtopics of Force and Energy are also suitable for teaching with ICT tools. When considering other topics, yes, it's possible to use ICT tools in all of them, but I consider them essential in some topics. For example, when explaining mitosis-meiosis, it's not as effective and understandable with traditional methods. But when you use ICT tools, the shape, movement, and rapid formation of a sperm become amusing, and students enjoy watching. It becomes more understandable when they see and watch these things.

Cenk emphasizes the importance of using ICT tools, especially animations and visuals, to explain complex and abstract topics in the science class design [KoCD; subject content]. He recognizes that these abstract concepts are challenging for students to grasp without visual aids and believes that visuals facilitate better content understanding [KoSC; facilitating to understanding the content]. This demonstrates how his curriculum design choices (KoCD) are informed by the aim of facilitating better content understanding (KoSC).

In summary, Cenk's teaching approach demonstrates a dynamic interplay between his knowledge of curriculum design (KoCD) and his efforts to facilitate content comprehension (KoSC). This interplay is evident in his use of virtual experiments, science process skills, and lecturing techniques to enhance students' understanding of scientific concepts. Moreover, Cenk's emphasis on the strategic use of ICT tools, particularly animations and visuals, highlights his commitment to improving content comprehension. The total number of interplays identified in the data was five, which

are two-way interactions between KoCD and KoSC.

4.2.3.5. The Interaction between KoPiT and KoA

The interplay between KoPiT and KoA involves teachers' expertise in addressing ICT challenges, managing instruction to meet student needs, and guiding effective technology use in science assessments. When examined Cenk's TPACK episodes including codes under the categories of KoPiT and KoA, there are several evidence reflecting KoPiT-KoA interplay.

Similar to Asaf and Bora, Cenk's data indicated that most of the interactions were observed between in-class formative assessments activities and ICT guidance. It was observed in one of his classes (Observation of Cenk's 6th class session) that Cenk actively encouraged his students to utilize ICT tools during classroom activities when he presented a ranking question that required students to interpret a table. Then, Cenk called a student to the board to ask her to read the question, and then instructed her on how to interpret the table. The student correctly pointed out that object X had the greatest kinetic energy due to its higher speed while she was requested to use the pen tool to write ' $X > Y$ ' on the screen. Furthermore, the student correctly stated that object Z had the greatest kinetic energy due to its higher mass and the same speed as X, and she wrote ' $Z > X$ ' on the screen. Consequently, the correct ranking became ' $Z > X > Y$.' This observation highlights the interaction between Cenk's encouragement of students to use ICT tools [KoPiT] and his utilization of in-class formative assessment techniques [KoA] to effectively engage students in technology-enhanced learning experiences. This dynamic interaction not only enhances students' active participation in technology-enhanced learning experiences but also fosters their ICT proficiency, resulting in more comprehensive and participatory assessments.

Cenk's guidance for ICT not only comprises to encouraging his students to use ICT but also includes his guidance to teach them to use ICT while learning. For instance, in one of his classes (Observation of Cenk's 6th class session), Cenk opened the browser on the smart board to access the internet. Using a specific keyword, he conducted a Google search to seek relevant resources. Eventually, a PDF document named objective comprehension test on work and energy topic consisting of multiple-choice questions was opened. During the class, a student was called to the board to

read a question aloud, which required demonstrating an understanding of a concept related to the different weights of an object on Earth and the Moon. Upon reading the question, the student paused to think. Recognizing the student's hesitation, Cenk encouraged critical thinking by asking if it was possible to determine what the dynamometer measures. The student acknowledged the possibility but appeared uncertain about the approach. In response, Cenk prompted the student to consider the number of loops between the point where the object was suspended and the dynamometer by asking 'Can we count how many loops there are?' The student responded with '1' and '6', respectively. Then, Cenk suggested adding these numbers next to the relevant diagram on the screen. The student quickly adapted and used the pen tool to write '1' and '6' alongside the diagram. Cenk further guided the student's understanding by referring to the information in the question, mentioning that each unit of movement corresponded to 10N. The student efficiently grasped this concept by responding that they could multiply by ten. Consequently, the student calculated the weights as 10N and 60N, annotating these values next to their previous annotations (1×10 and 6×10). This observation highlights the synergy between Cenk's guidance in using ICT tools for learning [KoPiT] and the implementation of in-class formative assessments [KoA]. Through the effective integration of technology and interactive teaching methods, Cenk guided students to engage critically and comprehend concepts during the assessment process. In this example, Cenk's proficiency in guiding students to learn using ICT tools influences how he conducts in-class formative assessments effectively.

As obtained from the observation data, Cenk's statements during the interview also support the existence of KoPiT-KoA interplay. For example, Cenk discusses how he encourages his students to actively utilize ICT tools during in-class and out-class formative assessment processes. In his own words,

This is what I do: I send assignments from EBA. Or I send assignments from WhatsApp, BIP groups. These [assignments] provide feedback for me. I want them to send me over the phone or via e-mail to my computer. I'm checking how many students from the class solved it and how many of them solved correctly. I then validate by asking how they solved some questions in the lesson. I listen to the reasons for those who did not solve or those who can't solve.

Cenk employs digital platforms such as EBA, WhatsApp, and Bip groups to assign

homework to encourage students to engage with ICT tools for their assignments [KoPiT; encouraging student use of ICT]. The subsequent collection and examination of these assignments can be seen as out-class formative assessments [KoA]. Furthermore, Cenk checks how students solve specific problems during class, effectively conducting in-class formative assessments [KoA]. This approach highlights a seamless connection between his efforts to promote student ICT use for learning (KoPiT) and his in-class and out-class formative assessments (KoA), which collectively contribute to enhancing student engagement, understanding, and learning outcomes. Thus, it is evident that his proficiency in guiding students to use ICT contributes to his approach to both in-class and out-class formative assessments, enhancing the overall learning experience.

In summary, Cenk's teaching practices showcase a dynamic interplay between KoPiT and KoA. His active encouragement of ICT use in assessments not only enhances student engagement but also contributes to his approach to in-class and out-of-class formative assessments. This underscores how KoA informs KoPiT. Simultaneously, his proficiency in guiding students to use ICT effectively for learning informs his approach to formative assessments, creating a mutual relationship between the two components. This interplay potentially enriches the overall learning experience by fostering greater student engagement, comprehension, and improved learning outcomes. In terms of the number of these interactions between KoPiT and KoA, a total of twenty-nine interactions were seen in Cenk's data. The number of interplays identified in the data was twenty-nine, which are two-way interactions between KoPiT and KoA.

4.2.3.6. The Interaction between KoPiT and KoL

Since there were limitations in gathering comprehensive evidence through observation alone, a limited amount of evidence was obtained only from the interview to explain KoPiT-KoL interplay. Based on the Cenk's interview data, only one piece of evidence was obtained only from the interview to explain this interplay.

Cenk's interview data reflects a clear interplay between his KoPiT and KoL. He highlights that the use of technology in the classroom such as interactive whiteboard applications significantly increase student enthusiasm and participation. In his own

words, Cenk states his students' motivation when teaching with ICT as follows:

Students become very enthusiastic because it increases their participation in the class. In other words, when I pose a question, if three hands go up, when a question is posed through the smart board application, fifteen hands go up. Perhaps students become more motivated to interact with something beyond the routine teacher-student relationship. Additionally, coming to the board, touching it, providing answers by interacting with the computer, and the ticks and sounds that come up when they give correct answers make them even happier.

Accordingly, he believes that students are more eager to engage with lessons when presented through technology, and this increased motivation is evident in their active participation [KoL]. Cenk's observation that more students participate and engage when questions are posed through smart board applications demonstrates how his encouragement of ICT use [KoPiT] positively influences student motivation and participation. Additionally, the interactive aspects of using technology, such as students coming to the board, physically interacting with the computer, and receiving positive feedback in the form of ticks and sounds for correct answers [KoPiT], further enhance their motivation [KoL; recognizing ICT-based motivational strategies for students]. This highlights a bidirectional interaction where Cenk's encouragement of ICT use (KoPiT) informs and amplifies his recognition of ICT-based motivational strategies for students (KoL). The number of interplays identified in the data was only one.

4.2.3.7. The Interaction between KoPiT and KoSC

The interplay between KoPiT and KoSC integrates pedagogical expertise, effective ICT use, and strategies for delivering science content while focusing on harmonious content-ICT integration and enhancing student comprehension. However, due to limitations in gathering comprehensive evidence of KoSC through Cenk's observation and interview data, only one piece of evidence was obtained to explain this interplay.

Cenk's interview data illustrates a clear interplay between his KoPiT and KoSC. Cenk emphasizes the importance of ICT guidance for students by inviting students to interact with the smart board, discuss, defend their ideas, and form arguments on the smart board as follows:

That's why I lift them to the board one by one, so they can touch, discuss, defend

their ideas, and form arguments. I believe that both the most successful and the least successful should stand on the board. For this, I open suitable content on the smart board.

Accordingly, Cenk believes that both the most successful and the least successful students should engage with the content in this manner [KoPiT; encouraging student use of ICT]. To achieve this, Cenk carefully selects and opens suitable content on the smart board to align the ICT tools with the subject content [KoSC; paying attention to content-ICT tool appropriateness]. His understanding of the appropriateness of these tools for specific learning tasks enables him to guide his students in using them to enhance their learning experience. Thus, KoSC informs and supports his KoPiT. The number of interplays identified in the data was only one.

4.2.3.8. The Interaction between KoA and KoSC

The KoA-KoSC interplay involves using formative assessment strategies with ICT tools to align subject content delivery effectively. This ensures student understanding and enhances clarity in learning. When examined Cenk's TPACK episodes including codes under the categories of KoA and KoSC, there is only one evidence reflecting KoA-KoSC interplay.

In Cenk's observation data, there is a clear interplay between his KoSC and his KoA as he effectively utilizes formative assessment strategies to facilitate his students' understanding of the content. During the observation (Observation of Cenk's 14th class session), Cenk noticed that the class had a low response rate to some questions. In response to this, he opened a PDF document containing the summary notes of the entire unit stored in his flash drive. This document provides quick definitions of key concepts and their relationships, which he uses as part of an in-class formative assessment strategy [KoA]. Cenk often refers to this resource and continues to work with the students to fill in the concept map together. Cenk's effective use of course summaries, quick definitions, and concept mapping as teaching strategies reflects his deep knowledge of the subject content, which he leverages to enhance student comprehension and engagement in the classroom [KoSC; facilitating to understanding the content]. This showcases how Cenk's subject expertise informs his assessment strategies by using these summaries as a tool to support student learning and comprehension. The number of interplays identified in the data was only one.

4.2.3.9. The Interaction between KoL and KoA

The KoL-KoA interplay involves dynamically using ICT-based formative assessments to align with students' cognitive development, learning needs, and preferences, enhancing learning experiences within the ICT environment. When examined Cenk's TPACK episodes including codes under the categories of KoL and KoA, there is limited number of evidence reflecting KoL-KoA interplay.

According to Cenk's statements during the interview, it seems that there is a clear interplay between his awareness of students' learning difficulties with ICT (KoL) and his in-class formative assessment strategies (KoA). For example, Cenk actively engages with his students during lessons by asking them how they solve certain questions to provide him with valuable insights into their comprehension [KoA]. In his own words, Cenk states,

... I listen to the reasons for those who did not solve or those who can't solve. Their access to ICT tools is either non-existent or limited. But the participation of those who have limited access is good... I feel that the assignments achieve my goal.

He also listens to those who could not solve the problems or faced challenges. Notably, Cenk acknowledges the limited access to ICT tools among some students. He highlights that not all of them have access to these resources, which points to his awareness on his students' learning opportunities at home [KoL; awareness of students' learning difficulties with ICT]. Cenk actively engages with his students during lessons, particularly when they're facing challenges in solving certain questions. Cenk's use of in-class assessments like asking students about how they solve problems and why they could not, helps him understand their comprehension and any difficulties they face. The information gathered through in-class formative assessment helps him recognize the specific learning difficulties his students face, including those related to ICT tools. For instance, when he mentions that some students have limited or no access to ICT tools, it is likely that he learned about this issue through his interactions with them during in-class assessments. Therefore, Cenk's in-class formative assessment practices (KoA) inform his awareness of students' learning difficulties with ICT (KoL). His active engagement with students and their responses during assessments provide him with a deeper understanding of their individual

learning challenges, including those related to technology access.

Cenk's statements further illustrate his KoL-KoA interplay as he describes the use of a game-like application for solving science questions. He explains this as follow:

Besides that, for example, there is an application in a game style. There is a game consisting of questions related to the lesson. I access this game from a website called Fenus, where the character in the game escapes from monsters by answering questions correctly, and they can get free when they answer all the questions. Children really love such games.

Accordingly, Cenk acknowledges that children greatly enjoy this game-based learning approach during practicing exercise questions. Therefore, Cenk's awareness of his students' inclination towards such motivating ICT strategies significantly [KoL; recognizing ICT-based motivational strategies for students] informs his in-class formative assessment practices [KoA]. Thus, Cenk's utilization of these motivating ICT strategies not only enhances student engagement but also informs his in-class formative assessment practices, reflecting a dynamic interplay between KoL and KoA.

In summary, Cenk's KoL-KoA interplay is evident in his understanding of how his students' learning difficulties with ICT inform his in-class formative assessment strategies. He actively engages with students to gain insights into their comprehension and challenges, using in-class assessments. Cenk also employs motivating ICT strategies, like game-based learning, based on his awareness of students' preferences. This dynamic interplay enhances engagement and informs his formative assessment practices for improved learning outcomes. The total number of the interplay was estimated as two.

4.2.3.10. The Interaction between KoL and KoSC

The KoL-KoSC interplay strategically uses technology to enhance student understanding by addressing their learning needs, but obtaining data on these components can be challenging due to their complexity. When examined Cenk's TPACK episodes including codes under the categories of KoL and KoSC, there is limited number of evidence in the data reflecting KoL-KoSC interplay.

It was observed that there is an interplay between his KoL and KoSC. During one of his classes (Observation of Cenk's 4th class session), he opened an exercise question

related to an experiment focusing on change in kinetic energy with varying masses. After solving the question, Cenk asked to the class if there were any unclear aspects of the experiment. Since the students remained silent, he promptly recognized a potential issue with students' difficulty in comprehending the question or concepts within the question [KoL; awareness of students' learning difficulties with ICT]. Subsequently, he opened the explanatory video related to the experiment to address this issue effectively. After showing this explanatory video at the end of the experiment, Cenk revisited the experiment's findings and elucidated how kinetic energy is generated and what factors influence it to provide additional clarification [KoSC; facilitating understanding of the content]. This dynamic interplay between Cenk's KoL and KoSC underscores his ability to identify students' learning difficulties and implement technology to enhance their understanding of scientific concepts.

There is further evidence indicating Cenk's KoL-KoSC interplay in the interview data. He demonstrates a keen awareness of the power of ICT tools, particularly visual aids like animations, in enhancing students' comprehension and engagement with challenging and abstract topics. For example, he acknowledges that concepts such as atoms can be particularly difficult for students to grasp due to their abstract nature. However, Cenk finds that using visuals, especially animations, greatly improves the clarity and accessibility of these topics [KoSC; facilitating understanding of the content]. In addition, Cenk believes that ICT tools are suitable for conveying especially abstract concepts effectively. While he acknowledges that ICT tools can be useful for various subjects, he considers them indispensable for certain topics such as mitosis and meiosis. In his own words, Cenk states *"But when you use ICT tools, the shape, movement, and rapid formation of a sperm become amusing, and students enjoy watching. It becomes more understandable when they see and watch these things."* Cenk believes that traditional teaching methods are less effective in these cases, but the learning experience becomes enjoyable, engaging, and more permanent for the students [KoL; recognizing ICT-based motivational strategies for students]. This clearly illustrates Cenk's skill in leveraging his KoL to recognize ICT-based motivational strategies for students and applying them to enrich students' understanding and enthusiasm for the content he teaches. Thus, his KoL informs his KoSC since his awareness of students' motivational needs and his ability to recognize

ICT-based motivational strategies allow him to enhance students' understanding and enthusiasm for the content he teaches.

In summary, Cenk's instructional practices clearly demonstrate interplay between his KoL and KoSC. In his classroom, Cenk adeptly identifies students' learning difficulties and leverages technology to address them. Thus, this enhances their understanding of complex scientific concepts. He utilizes visual aids to make abstract topics more accessible and engaging for his students so that he recognizes the effectiveness of ICT tools in catering to their motivational needs. This synergy between his understanding of students' needs and strategic technology use underscores his ability to deepen comprehension and ignite enthusiasm among his students. Overall, Cenk's KoL effectively informs and enhances his KoSC. In terms of the number of these interactions between KoL and KoSC, a total of three interactions were seen in Cenk's data.

4.2.3.11. The TPACK-P Map of Cenk

The interactions among each TPACK-P component that emerged through the in-depth analysis were illustrated in the TPACK-P map (Figure 21). The creation of this map was elaborated on in the methodology chapter in detail. Based on the findings from Cenk's data, the following highlights were identified:

- The interplay between KoA and KoPiT is notably strong in comparison to other interplays. This highlights that Cenk's robust integration of assessment practices is particularly influential in guiding students' ICT use.
- While interplays exist between KoA-KoSC, KoPiT-KoSC, KoL-KoA, KoCD-KoA, AND KoP,T-KoL, they appear to be relatively weak, indicating Cenk's limited integration or influence between these components.
- Cenk's TPACK-P map encompasses all potential interactions among each component, demonstrating his extensive grasp of technology integration although some of these interactions may not be as strong as others. This comprehensive connectivity underscores his adeptness in utilizing technology effectively.
- The strongest interactions center around the components of KoPiT and KoA,

highlighting Cenk's effective integration of assessment practices as well as his adept ICT guidance for students' use. These components play a central role in shaping his TPACK-P framework.

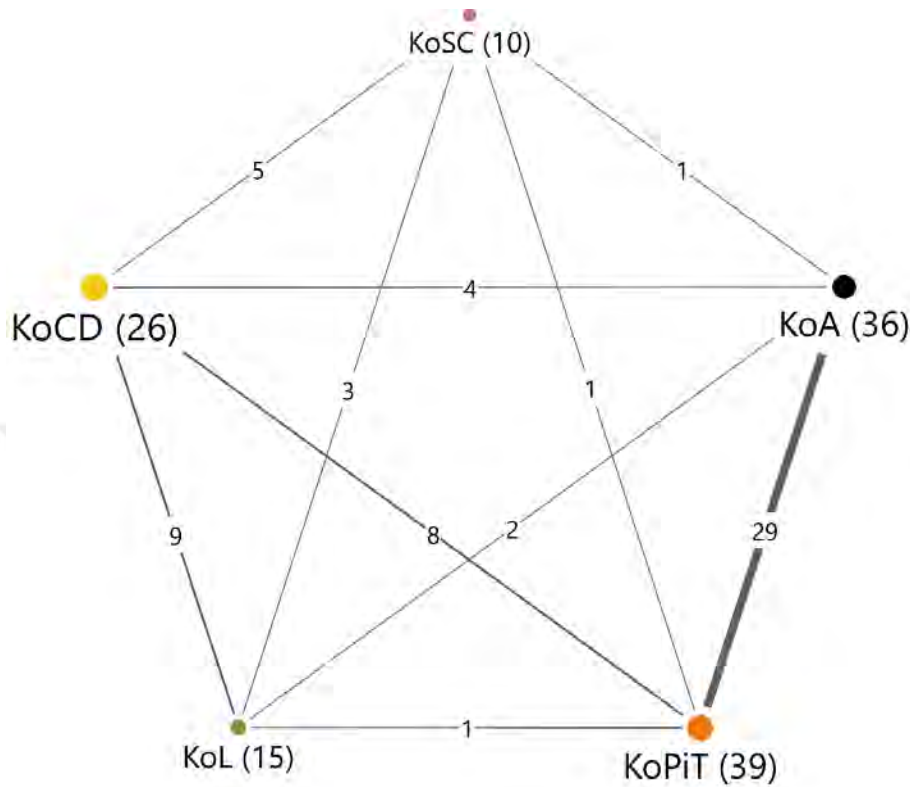


Figure 21. Cenk's TPACK-P map

4.2.4. Case 4: Esin

In this section, a detailed analysis of the interplay among TPACK-P components in Esin's case was presented by considering ten potential interactions between these components. Each interaction was explored to provide insights into the nature of Esin's TPACK-P and how these components inform each other.

4.2.4.1. The Interaction between KoCD and KoA

The interplay between KoCD and KoA involves strategically integrating technology into science lessons through the selection of ICT representations and teaching techniques aligned with curriculum objectives. When examining Esin's TPACK episodes with the related codes under the category of KoCD and KoA, evidence of KoCD-KoA interplay is evident.

It was observed that Esin assigned a design task to her students after completing teaching all topics of the unit (Observation of Esin's 12th class session). On that lesson, Esin incorporated a design task into her curriculum where students were required to draw a simple and digital vehicle considering the effects of air or water resistance to minimum [KoCD; designing model/product).

Concurrently, this task served as an assessment based on product development [KoA] as students were expected to showcase their understanding of scientific principles through their designs.

Moreover, she encouraged creativity and critical thinking in her students by allowing them to improve existing tools or come up with imaginary designs.

Thus, Esin's learning task choice, namely incorporating a design task focusing on the effects of air or water resistance, guide the assessment strategy employed in the classroom (KoA).

Likewise, Esin used educational games in her teaching while assessing her students.

It was observed in one of her classes (Observation of Esin's 13th class session) that she opened PDF presentation file to show some brief notes of the concepts and terms as well as for solving exercise questions.

Later, Esin incorporated an educational game [KoCD] into the classroom using a website called learningapps.org, where there was an online matching card game related to weight and mass (Figure 22).

This game served as an in-class formative assessment [KoA] as the students were actively engaged in answering questions and demonstrating their understanding of the concepts.

Thus, this example demonstrates how Esin's curriculum design choices (KoCD) inform and shape the assessment strategies (KoA) employed in the classroom to enhance the learning experience for students.



Figure 22. Image of matching card game used by Esin on the smart board

During the interview, Esin portrays her teaching style when delivering the topics. She mainly embraces the guided lecturing which is quite teacher-centered instruction but gives opportunities to students to actively participate by answering questions, attending mini discussions, or other sort of activities. In her own words, Esin states that “... no matter what I start with, I always show something on the smart board. This usually continues with a brief interactive conversation or a thought-provoking question. After that question, I ask students small questions in return.” This guided lecturing approach [KoCD] fosters short discussions and thought-provoking questions, encouraging limited but meaningful active participation from the students. She completes her statements, “... In the later parts of the lesson, when incorrect learning is evident in both the responses to the questions I asked and the problems solved on the smart board, I focus on addressing them.” By using such formative assessment strategies [KoA] throughout the lesson and while solving problems on the smart board, Esin addresses any incorrect learning or misconceptions to ensure effective learning. Therefore, Esin’s use of in-class formative assessment (KoA) informs her guided lecturing method (KoCD), indicating a thoughtful interplay between these two aspects in her teaching practices.

In summary, the examination of TPACK episodes and observations in Esin’s classes

provides evidence of KoCD-KoA interplay in her teaching practices. Esin's curriculum design choices guide the assessment strategies used in the classroom. Additionally, her use of in-class formative assessment (KoA) complements her guided lecturing approach, encouraging meaningful student participation during discussions and question-solving. The total number of interplays identified in the data was seven, which are two-way interactions between KoCD to KoA.

4.2.4.2. The Interaction between KoCD and KoPiT

The interplay between KoCD and KoPiT involves Esin's active guidance and engagement of students in ICT-infused learning, which includes the use of ICT-based representations, teaching strategies, and learning tasks. This also includes understanding the factors that influence the ICT-based design in alignment with the science curriculum. When analyzing the relevant TPACK episodes of Esin, clear pieces of evidence of KoCD-KoPiT interplay emerged.

During the observation in one of the Esin's class (Observation of Esin's 12th class session), she established a clear interplay between KoCD and KoPiT. She utilized an interactive experiment related to force applied and work done [KoCD; interactive experiment] to help students understand the relationship between these two concepts. Through the interactive experiment and controls on the smart board, she guided the students in using science process skills such as data collection, observation, hypothesis testing, and data analysis [KoCD; using science process skills]. By engaging in hands-on experimentation with the interactive experiment, the students developed their scientific inquiry skills and learned how to apply these skills in the context of ICT-infused learning [KoPiT; encouraging student use of ICT]. Accordingly, Esin's approach effectively combines hands-on learning tasks with the use of ICT tools to promote a deeper understanding of the scientific concepts being explored. Thus, KoPiT informs and influences KoCD in Esin's teaching approach.

Similarly, there are further evidence of Esin's use of ICT representations is influenced by her guidance in encouraging student use of ICT tools effectively. When solving some exercise question (Observation of Esin's 5th class session), Esin opened a visual showing an object hanging from the ceiling with a string, and the object is being displaced horizontally. The question on the screen requested which of the forces acting

on the object does work. The options included the force F that moves the object, the weight of the object, and the tension force in the string. The next student opened the drawing tool and drew the direction of motion by saying ‘We should look at the forces in this direction.’ In this instance, Esin uses an interactive visual representation [KoCD; interactive experiment] to engage students in understanding the concept of forces and work done. The student actively participates by using ICT tools to draw the direction of forces on the visual [KoPiT; encouraging student use of ICT]. Esin’s approach of presenting the visual and asking questions prompts student to analyze the forces and determine which one does work [KoCD; establishing relationship between concepts]. Thus, KoPiT informs KoCD since Esin’s guidance in Encouraging student use of ICT tools effectively (KoPiT) prompts student to actively participate by using the drawing tool to analyze the forces and determine which one does work (KoCD).

Esin’s statements during the interview also indicate a close relationship between her KoCD and KoPiT in her teaching approach. According to Esin,

... It’s not just knowledge [I want them to have]. [I want the students to] stand up on the smart board and do experiment there, change the variables, develop, and test hypotheses. In other words, I want them to acquire scientific process skills as well.

Based on these statements, there is a clear interplay between KoCD and KoPiT in Esin’s teaching approach. She emphasizes curriculum goals [KoCD; science program goals] by stating her aim of having students grasp the main concepts and achieve a solid understanding of the subject matter. On the other hand, Esin focuses not only on acquiring knowledge but also on developing scientific process skills such as conducting experiments, manipulating variables, formulating hypotheses, and testing them [KoCD; using science process skills]. Esin accomplishes this by guiding them to demonstrate on the smart board by doing-it-themselves [KoPiT; encouraging student use of ICT]. The interplay between KoCD and KoPiT in Esin’s teaching approach helps students become engaged in the learning process. Thus, the interplay between KoCD and KoPiT is evident in Esin’s approach. Her emphasis on curriculum goals (KoCD) informs and influences her approach to integrating ICT tools and guiding students in developing scientific process skills (KoPiT). In turn, the use of ICT tools by students and their active participation in scientific activities (KoPiT) enhances students’ understanding of the subject matter and reinforces the curriculum goals

(KoCD).

Esin also states his design choices were influenced by her students' expectations. For example, Esin stated that her teaching approach fosters student engagement and satisfaction in the classroom. As one student mentioned in Esin's own words, *"I don't like that other class, and most of my friends don't like it either... But our other teacher in that class even forbids us from touching the smart board's surface. That's why we want that class to end quickly and yours to start."* This highlights the impact of Esin's use of ICT and interactive teaching methods that were welcomed by students. Another important finding is that the students' positive response is reflected in their performance, as noted by Esin, *"I can observe it from the questions they solve and the grades they receive in exams."* as well as *"I understood that if we want children to learn, we need to structure the lessons in a way that they will enjoy"* This indicates that the students' satisfaction and engagement positively influence their learning outcomes [KoCD; student satisfaction]. Esin's teaching approach not only encourages student satisfaction but also promotes their active use of ICT tools during the learning process, as she guides them to interact with the smart board and actively participate in activities [KoPiT; encouraging student use of ICT]. Moreover, the success of her class in science compared to others underscores the importance of structuring lessons in a way that caters to students' enjoyment and expectations. Thus, the interplay between student satisfaction as a design factor of ICT-based class (KoCD) and Encouraging student use of ICT (KoPiT) is evident in Esin's teaching approach, indicating a direction from KoCD to KoPiT. This means that Esin's emphasis on student satisfaction and engagement with ICT-infused learning influences her approach in making students actively use ICT tools during the learning process.

Another evidence for KoCD-KoPiT interplay in Esin's data was obtained from his statements during the interview. Esin discusses the advantages and disadvantages of using ICT tools in the classroom. Esin states her opinion on disadvantages of ICT use in the class as follows:

In fact, these tools are very advantageous (*she thought for a long time*). But, for example, some tools or techniques can be time-consuming for me. Once, I tried using a concept mapping program. However, it took so much time to open the application, write each concept, and draw arrows that only a small portion of what I wanted to cover that day was completed. So, I don't think some tools are

good in terms of time efficiency. After all, we have to follow a program and cover our topics.

Although recognizing the benefits of ICT, she also acknowledges that certain tools or techniques can be time-consuming [KoPiT; ICT advantages/disadvantages] that may lead to inefficiencies in classroom management, specifically when using a digital concept mapping software [KoCD; concept mapping] on smart board. Accordingly, this reveals the interplay between ICT advantages/disadvantages (KoPiT) and ICT-integrated teaching methods (KoCD), where Esin's teaching approach (concept mapping) is influenced by the need to adhere to the science curriculum [KoCD; science program goals] and timely coverage of topics. Additionally, Esin mentions using the EBA platform for assigning homework and sharing announcements. In her own words,

I give homework through EBA (Education Information Network). Let's say I used it more actively. I shared announcements, activities, and many other things with the students through EBA. But then, limited access to EBA could be a disadvantage for some students, and they might even disconnect from the lesson because of it.

Apparently, she recognizes its benefits while she notes the disadvantage of limited access [KoPiT; ICT advantages/disadvantages] for some students, which could lead to disengagement [KoCD; ICT access]. Esin's considerations of both the advantages and disadvantages reflect the alignment with science program goals and the importance of providing equitable learning opportunities for all students. Thus, KoPiT informs KoCD because Esin's considerations about the advantages and disadvantages of using ICT tools influence her decisions about how and when to use these tools to ensure equitable access for all students.

Finally, Esin's instructional management skills with ICT use was influenced by her consideration of what her students expect from her. She explains this as follows:

I didn't see myself as a teacher with good classroom management. However, when I compared myself to my colleagues in the teachers' lounge, I realized that I have better control. I believe this is because I am able to capture students' attention and engagement by incorporating activities and other instructional tools that they enjoy... This prevents serious disruptions in the classroom, and the class environment does not consist of students who sabotage the lesson. Therefore, I believe that my classroom management is effective due to the way I conduct the lessons.

Accordingly, Esin recognizes her ability to maintain better control [KoPiT; managing the classroom] compared to some of her colleagues. She attributes this achievement to her approach of engaging students in activities they enjoy and find interesting [KoCD; student satisfaction], which helps them focus on the lesson and prevents disruptive behavior. Esin mentions that by incorporating activities and tools that appeal to students, such as interactive tasks, she creates a positive classroom climate where disruptions are minimized and students are motivated to participate. As a result, she believes that her teaching approach positively influences classroom management.

In summary, the interplay between KoCD and KoPiT in Esin's teaching approach involves active guidance and engagement of students in ICT-infused learning, emphasizing curriculum goals, scientific process skills, and student satisfaction. Esin's approach also considers the advantages and disadvantages of using ICT tools. The interplay is evident in how Esin integrates ICT tools and guides students in developing scientific process skills, while her instructional management with ICT is influenced by considering students' expectations, leading to effective classroom management. Overall, the interplay between KoCD and KoPiT is evident in Esin's teaching approach, informing and influencing each other to enhance student engagement and learning outcomes. The total number of the interplays was estimated as fourteen.

4.2.4.3. The Interaction between KoCD and KoL

The interplay between KoCD and KoL involves considering students' cognitive development, learning difficulties, and preferences when designing ICT-based science classes in alignment with the science curriculum. Upon analyzing TPACK episodes and codes under the categories of KoCD and KoL, multiple instances reflecting the KoCD-KoL interplay were observed in Esin's data.

The data gathered from observations of Esin's classes and her interview reveals insight for KoCD-KoL interplay. For example, in one of her classes (Observation of Esin's 1st class session), Esin initiated the smart board and announced that they start a new unit. To captivate the students' attention and curiosity, she posed a question regarding astronauts' movements in space as compared to our movements on Earth. This showcases her awareness of utilizing ICT-based motivational strategies to engage students [KoL; recognizing ICT-based motivational strategies for students]. Later, she

let them think for a while and then she showed an animation on the smart board using EBA [KoCD; animation]. Esin's choice of animation as an ICT representation is influenced by her understanding of the need for visual aids to enhance learning. The alignment between her utilization of animations and her recognition of students' motivational triggers reflects how KoL informs KoCD in her teaching strategy.

Similarly, Esin's statements provide further evidence of the dynamic interplay between her understanding of students' learning needs and her instructional decisions. She describes this in detail how she does these to regulate her design as follows:

I generally prefer to start my lessons with an example or visual aid such as a video or an image that will capture students' maximum attention. If at the beginning of a lesson, the students don't focus all their attention on me or what I'm showing, I believe I lose them right from the start. I know that what children see on the smart board holds their interest, so no matter what topic I'm covering, I show something on the smart board. This usually leads to a short, interactive conversation or a thought-provoking question. Following that question, I ask students smaller questions in return. I make short question-answers to the students. For example, when I started the unit, I made them watch astronauts doing spacewalks and asked why they looked like they were flying. Starting from here, we moved on to the subject of mass, gravitational force. In these question-answers, I try to understand the general knowledge level of the class, what they remember from previous years, what they learned wrong by asking as many different students as possible.

Accordingly, Esin's teaching approach demonstrates a dynamic interplay between KoCD and KoL. First, Esin strategically employs ICT-based motivational strategies to enhance student engagement. Esin begins her lessons with captivating examples or visual aids like videos and images [KoCD; video, picture/photo], knowing that they will capture her students' maximum attention [KoCD; recognizing ICT-based motivational strategies for students]. Esin's emphasis on capturing students' attention aligns with her recognition that children's interest is increased by what they see on the smart board. She further explains her instructional process that allows her to gauge students' understanding and gather insight into their comprehension levels [KoL; checking students' background knowledge using ICT]. Although she does this by using interactive and thought-provoking questions to facilitate student participation, Esin's full control reflects that she adopts guided lecture teaching method. This instructional strategy not only maintains students' focus but also provides them with an opportunity to actively participate and express their thoughts. By asking follow-up

questions and eliciting short question-answer exchanges along with what she presents on the smart board, Esin gauges students' comprehension levels [KoL; checking students' background knowledge using ICT]. Furthermore, Esin's statements also illustrate how her KoL informs her KoCD. Her emphasis on understanding the general knowledge level of the class, and identifying what students remember from previous years is a clear sign of her consideration of learners' needs and comprehension levels. This understanding shapes her instructional decisions, such as introducing the topic of mass and gravitational force after the discussion on astronauts' movements on space. This instructional sequence highlights Esin's dynamic approach, where her recognition of students' learning needs (KoL) informs the sequence and content of her curriculum design (KoCD). Thus, her teaching approach demonstrates a dynamic interplay where her KoL influences her KoCD.

Esin also mentions how she detect misconceptions of her students in class. Accordingly, although she utilizes specific ICT tools to identify misconceptions, she states that she is quite aware of the common misconceptions for each topic. She achieves this before starting new topic by checking an academic report that contains common misconceptions in science classes. She explains this as follows:

A course I took while I was in graduate school was on misconceptions. In an article I read, I was interested in a study that compiled the most common misconceptions in science lessons. I still have that article on my computer. I often check that article before I start the topic of the class I teach. In this unit, for example, assuming that every moving object does work, the greater force does greater work ... I try to choose content for the children to focus on. In other words, when I come to a section about this in an animation, I stop the animation and ask questions such as 'do you think this is always the case?'. So, I always catch one or two [misconceptions] in each unit.

Accordingly, her proactive identification of students' misconceptions informs her curriculum design. By utilizing specific ICT tools like animations [KoCD; animation], she engages students in discussions that challenge their misconceptions [KoL; identifying students' misconceptions using ICT]. This strategic alignment between recognizing common misconceptions and incorporating interactive learning elements shows a good integration of KoL and KoCD in shaping her effective teaching strategy.

Moreover, Esin's statements also present insight on the interplay between KoCD and KoL. When asked about how she design ICT-based class according to different

learning characteristics of students, Esin explains this as follows:

I try to use as rich content as possible. EBA really seems like a sufficient platform for me in this regard. Because children are less able to listen; they love watching and getting up and touching and interacting. I also make an effort to avoid straight lecturing and instead strive to make them talk and engage in activities. Whether it's the practice questions in the EBA or the questions I open from other sources, I try to have students solve all these in turn, trying to both meet their needs and see different content. For example, they love the experiments and games we do on the smart board. For instance, sometimes I make them play a game called 'Who Wants to Win 500 Points?' which consists of science questions. They become incredibly pleased.

According to these statements, Esin's teaching approach exemplifies the interplay between KoCD and KoL. By choosing ICT-based experiments or games like knowledge contest [KoL; recognizing ICT-based motivational strategies for students] as well as being aware of what students would like to do during the class such as listening less are the signs of her knowledge on her students' motivation sources and learning styles. Therefore, this knowledge informs her tailored curriculum design, ensuring effective engagement. Employing virtual experimenting and educational games [KoCD], Esin designs lessons that are filled with valuable content and deeply connect with her students. Aligning with her emphasis on guided lecturing [KoCD], she not only adapts her teaching methods to suit students' learning styles [KoL] but also employs a range of ICT tools to foster engagement and motivation [KoL]. This dynamic interaction between KoCD and KoL ensures that her teaching strategy remains captivating and impactful, cultivating an optimal learning environment for her students. Thus, the interplay between KoCD and KoL in Esin's teaching approach is bidirectional. While her awareness of students' motivational sources and learning styles (KoL) informs the way she designs her curriculum (KoCD), her curriculum design choices (KoCD) also influence her understanding of her students' learning needs and preferences (KoL).

In summary, the data collected from observations of Esin's classes and her interview highlights the dynamic interplay between KoCD and KoL. She strategically employs ICT-based motivational strategies and tailored curriculum design, demonstrating how her understanding of students' needs informs her instructional choices. Similarly, her emphasis on interaction and engagement leads to the use of virtual experimenting and educational games in her curriculum. This reciprocal influence between KoCD and

KoL ensures an engaging and impactful teaching strategy. The total number of the interplays between the components is a total of ten.

4.2.4.4. The Interaction between KoCD and KoSC

The interaction between KoCD and KoSC involves a strategic selection of ICT elements aligned with science curriculum objectives. Upon analyzing Esin's TPACK episodes associated with the specific codes within KoCD and KoSC, the presence of this interplay between the two components became evident.

In one of her classes (Observation of Esin's 4th class session), Esin initiated an experiment focused on understanding kinetic energy, emphasizing the use of science process skills and interactive experiments [KoCD; using science process skills, interactive experiment]. She guided students through the experiment, and made them to form hypotheses and make observations related to the relationship between speed and kinetic energy. Through this interactive experiment, students actively engaged in the scientific process. The experiment's results provided concrete evidence of the success of Esin's instructional approach in enhancing content comprehension [KoSC; facilitating to understanding the content] according to Esin's own expression. This demonstrates how Esin's KoCD informs the selection and implementation of instructional strategies that ultimately support the aim of facilitating content understanding (KoSC).

During the interview, Esin states that some topics is essentially need ICT tools for better understanding the content. She illustrates this as follows:

In my opinion, there is enough material and content for using ICT tools in all topics. But sometimes, in some topics, using ICT tools becomes necessary. For example, in a lesson where we explain the structure of DNA, if we verbally describe the self-replication of DNA or show a couple of pictures, it's not effective. But if we show an animation or a fun video illustrating it, it sticks in the children's minds. So, I say that when teaching processes or procedures that are difficult to understand, these tools are helpful.

Accordingly, Esin highlights the importance of utilizing ICT tools, such as videos and animations, in the teaching process to enhance students' understanding of complex topics [KoCD; video, animation]. She emphasizes that while there is sufficient material and content available for using ICT tools across all subjects, there are

instances where the use of these tools becomes necessary, especially in topics that involve complex processes or procedures that are challenging to grasp [KoSC; facilitating to understanding the content]. Esin believes digital tools are crucial for some topics, like explaining DNA replication, where animations or engaging videos are more effective than words or pictures. This demonstrates how Esin's curriculum design choices (KoCD) are informed by the aim of enhancing content understanding (KoSC) through the strategic use of ICT tools.

In summary, Esin's teaching approach reflects an interplay between her knowledge of curriculum design (KoCD) and her knowledge of subject content (KoSC). She utilizes interactive experiments and emphasizes the importance of science process skills to actively engage students in the scientific process and enhance their content understanding (KoSC). Additionally, Esin recognizes the necessity of ICT tools like videos and animations in certain topics, highlighting how her KoCD informs her instructional choices to better support content comprehension (KoSC). This demonstrates a clear connection between her curriculum design knowledge and her efforts to facilitate student learning. The total number of the interplays between the components is a total of five.

4.2.4.5. The Interaction between KoPiT and KoA

The interplay between KoPiT and KoA involves teachers' expertise in addressing ICT challenges, managing instruction to meet student needs, and guiding effective technology use in science assessments. When examined Esin's TPACK episodes including codes under the categories of KoPiT and KoA, there are several evidence reflecting KoPiT-KoA interplay.

Similar to other teachers, Esin's KoPiT-KoA interplay was mostly observed in her guidance of ICT during in-class formative assessment processes. To illustrate, it was observed in one of her classes (Observation of Esin's 2nd class session) that Esin opened the browser on the smart board and accessed the website kazanimtestleri.com to administer a comprehension test on the topic of mass and weight. The test consisted of multiple-choice questions, and students took turns standing up to solve the questions. In the first question, they were asked to match two given statements (1: quantity of matter, 2: varies with gravity) with their corresponding meanings. The

options included weight-mass, weight-weight, mass-mass, and mass-weight. In another question, a picture of a balanced scale was presented, and students were asked what measurement can be made with this tool. The options included weight, mass, force, and pressure. When the next student provided the answer ‘mass’, Esin asked about the unit of measurement, to which the student responded with ‘gram’. She confirmed that measurements are indeed made in grams or kilograms. Based on this observation, Esin administers comprehension tests using an online platform, encouraging students to actively participate and engage in discussions on topics like mass and weight. This approach serves both formative assessment purposes [KoA; in-class formative assessment] and encourages students to utilize ICT tools for learning [KoPiT; encouraging students to use ICT]. By combining technology-driven assessments with pedagogical guidance, Esin creates an interactive and engaging learning environment that enhances students’ comprehension and active participation. Thus, Esin’s pedagogical guidance for ICT use (KoPiT) informs and enhances her in-class formative assessment practices (KoA). Her effective integration of technology into comprehension tests not only facilitates formative assessment, allowing her to gauge student understanding, but also actively encourages students to embrace ICT tools for learning.

The statements of Esin also support how she encourage to participate to in-class assessment processes. Accordingly, Esin makes her students participate to those processes by presenting various assessment tools and activities. She describes this as follows:

Sometimes I do puzzles. There is a site called Puzzlemaker. I identify key concepts in units where there are many concepts and create the puzzle. Then I download the puzzle and its solution separately to my flash drive and show it to the students in the lesson. Children get up and answer the puzzle one by one with the pen tool on the smart board.

In this respect, Esin’s KoPiT-KoA interplay is prominently observed in her integration of ICT tools for in-class formative assessments. She actively employs online puzzle creation using a website called Puzzlemaker [KoA; in-class formative assessment]. Esin identifies key concepts within units that encompass numerous ideas and transforms them into puzzles. She saves both the puzzle and its solution separately to her flash drive and presents them to her students during lessons. In class, students are

encouraged to participate by taking turns solving the puzzles on the smart board using a pen tool [KoPiT]. This approach demonstrates how Esin's guidance for utilizing ICT tools (KoPiT) effectively enhances her in-class formative assessment practices (KoA), fostering active student participation and comprehension during assessments.

Furthermore, there is further evidence for KoPiT-KoA interplay when she explains how out-class formative assessment may result in a drawback for some students. In her own words, Esin states,

I assign homework through EBA. Let's say I used it always. I constantly shared announcements there, sent activities and many other things to the students through it. Then, there will be a disadvantage for students with limited access to EBA. That's why they might even fall behind in the class.

These statements highlight a potential disadvantage of relying on EBA for homework assignments and communication with students. While the active use of this platform can offer advantages in terms of engagement and resource sharing it may also create a digital divide, disadvantaging students with limited access to EBA [KoPiT; ICT advantages/disadvantages]. This interplay between leveraging technology for out-of-class formative assessment [KoA] and its potential consequences on student performance underscores the need for a balanced approach to ensure equitable learning opportunities for all students. Thus, Esin's active use of technology for out-of-class formative assessment (KoA) informs her instructional management with ICT integration by demonstrating the advantages and disadvantages of such an approach (KoPiT).

In summary, Esin's teaching practices showcase a dynamic bidirectional interplay between KoPiT and KoA. Her adept guidance for ICT utilization during in-class formative assessments effectively informs her instructional strategies to enrich the learning experience by promoting greater engagement, comprehension, and overall learning outcomes for her students. Simultaneously, her active involvement of students in in-class assessment processes highlights how KoA can enhance KoPiT. Additionally, her insights reveal potential disadvantages associated with technology-driven homework assignments. This interplay between leveraging technology for out-of-class formative assessment and its implications on student performance emphasizes the importance of a balanced approach to ensure equitable learning opportunities. In

conclusion, Esin's skillful management of both KoPiT and KoA contributes to a more engaging and effective learning environment for her students. In terms of the number of these interactions between KoPiT and KoA, a total of twenty-two interactions were seen in Esin's data.

4.2.4.6. The Interaction between KoPiT and KoL

The operational definition of the interplay between KoPiT and KoL involves considering students' cognitive development, learning difficulties, and preferences when applying instructional management skills and infusing ICT into the teaching context. However, despite the emphasis on this interplay, limitations were encountered in gathering comprehensive evidence through observation alone. Upon analyzing both observation and interview data for Esin, no clear instances or indications of an interplay between her KoPiT and KoL were identified.

4.2.4.7. The Interaction between KoPiT and KoSC

The interplay between KoPiT and KoSC integrates pedagogical expertise, effective ICT use, and strategies for delivering science content while focusing on harmonious content-ICT integration and enhancing student comprehension. However, due to limitations in gathering comprehensive evidence of KoSC through Esin's observation and interview data, no clear instances or indications of an interplay between her KoPiT and KoSC.

4.2.4.8. The Interaction between KoA and KoSC

The KoA-KoSC interplay involves using formative assessment strategies with ICT tools to align subject content delivery effectively. This ensures student understanding and enhances clarity in learning. When examined Esin's TPACK episodes including codes under the categories of KoA and KoSC, there is only one evidence reflecting KoA-KoSC interplay.

In Esin's observation data (Observation of Esin's 12th class session), clear evidence of an interplay between her KoSC and KoA emerges. This is evident in the way Esin effectively employs formative assessment strategies to facilitate her students' understanding of complex subject content related to weightlifting. When the selected

student initially struggled to provide the correct answer to the question on the smart board [KoA; in-class formative assessment], Esin prompted the student to recall the conditions required for work to be done. The student responded by mentioning the need for movement and the application of force in the same direction. However, when the student seemed unsure about what exactly constitutes weightlifting, Esin took deliberate actions to clarify. Accordingly, she instructed the student to use the internet search engine to find images related to weightlifting on the smart board [KoSC; facilitating to understanding the content]. This dynamic interaction illustrates how her KoSC enriches her assessment practices (KoA) that allows her to adapt teaching methods for enhanced student comprehension. In terms of number of the interplay, there was only one interplay between KoA and KoSC.

4.2.4.9. The Interaction between KoL and KoA

The KoL-KoA interplay involves dynamically using ICT-based formative assessments to align with students' cognitive development, learning needs, and preferences, enhancing learning experiences within the ICT environment. When examined Esin's TPACK episodes including codes under the categories of KoL and KoA, there is only one piece of evidence reflecting KoL-KoA interplay.

During explaining her teaching approach to students' different learning needs, Esin's statements reveals a dynamic interplay between her awareness of students' learning styles with ICT (KoL) and her in-class formative assessment strategies (KoA). She recognizes that her students prefer interactive and hands-on learning experiences over passive listening. Consequently, Esin actively avoids traditional lecturing and strives to engage her students by encouraging them to participate and interact with the content as she emphasizes *"Because children are less able to listen; they love watching and getting up and touching and interacting."* Esin explains further to ensure her students' exposure to a diverse range of content. This involves assigning a variety of exercises including those from EBA and other sources [KoA; in-class formative assessment] with a deliberate sequencing to address to their specific learning needs [KoL; adapting to students' learning styles with ICT]. In her own words, Esin states *"I also try to make students solve either exercise questions from EBA or questions from other sources to meet their needs and to expose them to various content."* Moreover, Esin effectively

employs smart board experiments and interactive games, such as ‘Who Wants 500 Points’ which focuses on science questions in line with her understanding of her students’ motivation ignitors. These methods not only engage her students effectively but also enhance their motivations to learn [KoL; recognizing ICT-based motivational strategies for students]. For instance, Esin notes, *“For example, they absolutely love the experiments and games we do on the smart board.”* to highlight this effect the use of such ICT tools when solving exercise questions [KoA]. Thus, Esin’s awareness of her students’ preferences for diverse learning materials (KoL) and her motivational strategies (KoL) informs her in-class formative assessment practices (KoA), which allows her to adapt her assessments to cater to their varying needs and preferences. In terms of number of the interplay, there was only one interplay between KoL and KoA.

4.2.4.10. The Interaction between KoL and KoSC

The KoL-KoSC interplay strategically uses technology to enhance student understanding by addressing their learning needs, but obtaining data on these components can be challenging due to their complexity. When examined Esin’s TPACK episodes including codes under the categories of KoL and KoSC, there is only two pieces of evidence in her interview data reflecting KoL-KoSC interplay.

Esin’s interview data highlights an interplay between her KoL and KoSC. She believes that there is adequate range of materials and content for utilizing ICT tools in teaching all science topics. However, she also acknowledges that there are situations where the use of ICT tools is essential when explaining complex processes or concepts for better learning. She illustrates this by giving an example from different science topic:

... if we verbally describe the self-replication of DNA or show a couple of pictures, it’s not effective. But if we show an animation or a fun video illustrating it, it sticks in the children’s minds.

Consequently, selecting ICT tools such as funny videos increase her students’ motivation to engage [KoL; recognizing ICT-based motivational strategies for students and comprehensions [KoSC; facilitating understanding of the content]. Moreover, she understands that employing the right technology can address students’ learning difficulties and enhance their comprehension. Therefore, it makes challenging subjects become more accessible and engaging [KoL; awareness of students’ learning

difficulties with ICT]. Esin explains how she overcome these issues with ICT tools as follows: “*So, I say that when teaching processes or procedures that are difficult to understand, these tools are helpful.*” This points to that Esin is able to select ICT tools based on what topics may be difficult to learn, which indicates her knowledge on content-ICT tool appropriateness [KoSC; paying attention to content-ICT tool appropriateness]. Thus, Esin’s KoL informs her KoSC as she strategically selects and incorporates ICT tools for enhancing students’ motivation and comprehension. She recognizes their potential to address learning difficulties and ensure content-ICT tool appropriateness in order to enrich her students’ learning experiences and understanding of complex content. In terms of the number of the interplays, there were two interplays between KoL and KoSC.

4.2.4.11. The TPACK-P Map of Esin

The interactions among each TPACK-P component that emerged through the in-depth analysis were illustrated in the TPACK-P map (Figure 23). The creation of this map was elaborated on in the methodology chapter in detail. Based on the findings from Esin’s data, the following highlights were identified:

- In Esin’s TPACK-P map, there are distinct thick lines between KoPiT and KoA and between KoCD and KoPiT. These powerful interactions demonstrate Esin’s expertise in translating technology into practical applications, particularly in assessing students with ICT and planning and designing ICT-based science teaching.
- In Esin’s TPACK-P map, although interactions exist between KoA-KoSC, KoL-KoSC, and KoL-KoA, these connections appear relatively weak, indicating limited integration or influence between these components.
- There are no clear instances or indications of an interplay between Esin’s KoPiT-KoSC and KoPiT-KoL connections. This underscores the lack of connection between her proficiency in ICT guidance, technological challenges, and instructional management in the class, and both her students’ diverse learning needs and her selection of appropriate ICT tools to better understand the science content.

- The highest number of interactions is observed with the KoCD component, which suggests that KoCD holds a more central position within Esin's TPACK-P map. This emphasizes that Esin's expertise in planning and designing important role in shaping her TPACK-P.

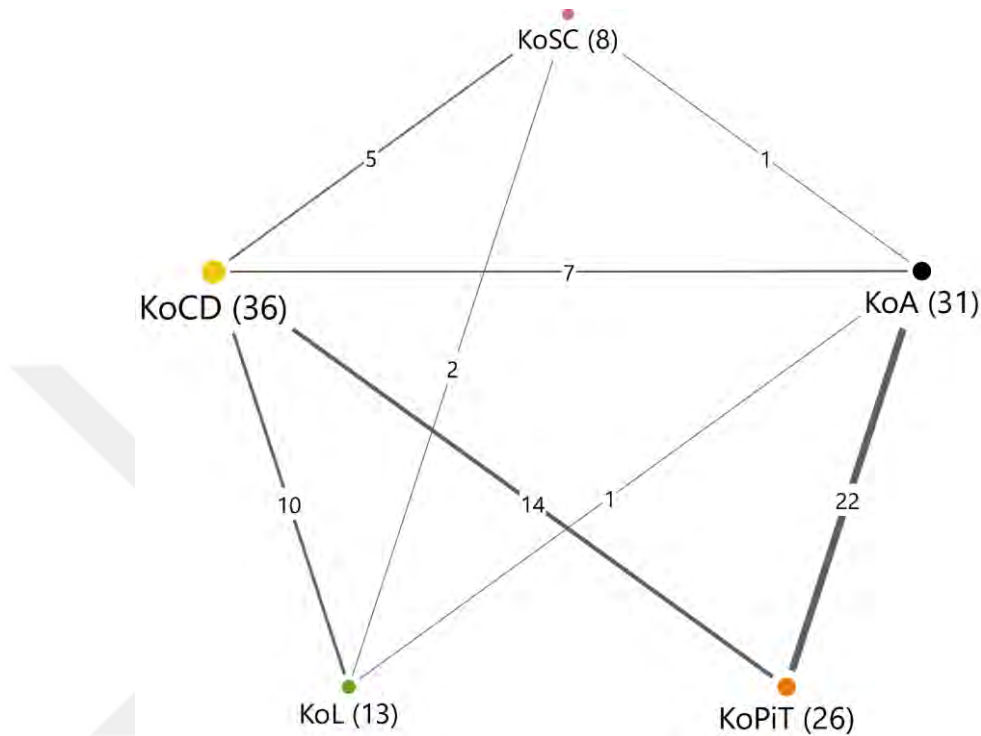


Figure 23. Esin's TPACK-P map

4.2.5. Comparing TPACK Maps and Formulated Assertions

When comparing the TPACK-P maps of Asaf, Bora, Cenk, and Esin (Figure 24), it becomes evident that distinct features and commonalities emerge in their approaches to integrating technology into teaching practices. When comparing the TPACK-P maps of the four teachers, following features becomes clear:

Overall Structure: The overall structures of the TPACK-P maps do not share a similar layout or arrangement of components. For instance, in Asaf's map, the components are organized in a way that highlights that the central role of ICT guidance, technology and class management in his teaching. In contrast, Esin's map exhibits a different layout, emphasizing the importance of planning and designing in technology-based science teaching. These differences in overall structure indicate that each teacher

tailors their TPACK-P map to their unique teaching context.

Prominent Interplays: When examining the TPACK-P maps of each teacher, it is evident that the most prominent interplays consistently occur between the components KoPiT and KoA. This consistent pattern across all maps highlights the central role of integrating assessment practices with ICT guidance during integration of technology in their teaching approaches. These interplays emphasize the importance of effectively using technology for assessment within their TPACK-P.

Number of Interactions: There is no consistent pattern of certain components being more interconnected across all maps. The number of interactions for each component varies, reflecting the teachers' diverse approaches to technology integration. For instance, while KoCD has significantly more interactions in Bora's and Esin's maps, it is KoPiT that exhibits the highest interactions in Asaf's and Cenk's map. This variability underscores the individualized nature of their technology integration strategies.

When contrasting the TPACK-P maps of the four teachers, following features become clear:

Unique Features: Each teacher's TPACK-P map exhibits unique features or components that distinguish their approach. For instance, Bora's and Cenk's maps contain all possible interactions, showcasing their comprehensive understanding of technology integration. In contrast, Asaf and Esin's maps lack certain interplays, indicating variations in their integration of specific components.

Differences in Interaction: There are notable differences in the number of interactions for each component. Some components have more prominent interactions in certain maps compared to others, reflecting variations in teaching practices and priorities. For instance, KoPiT-KoA, KoCD-KoPiT, and KoCD-KoL exhibit thicker lines (indicating more interactions) in Asaf's, Cenk's, and Esin's maps, highlighting the emphasis on integrating these components. In contrast, Bora's map shows thicker lines for KoPiT-KoA, KoCD-KoA, and KoCD-KoSC, suggesting a different focus in technology integration.

Weak or Nonexistent Interplays: Variations exist in the presence of weak or nonexistent interplays in each map. For instance, the interplays between KoL-KoSC are weak in Asaf's map, suggesting limited integration between understanding students' learning needs and the adaptation of subject content delivery with ICT. In contrast, Esin's map lacks clear interplays between KoPiT-KoSC, indicating a disconnect between effective incorporation technology into their teaching practices while selecting suitable science content to enhance learning, as well as KoPiT-KoL, suggesting potential gap in integrating technology according to students' learning needs. These differences highlight varying levels of technology integration among the teachers.

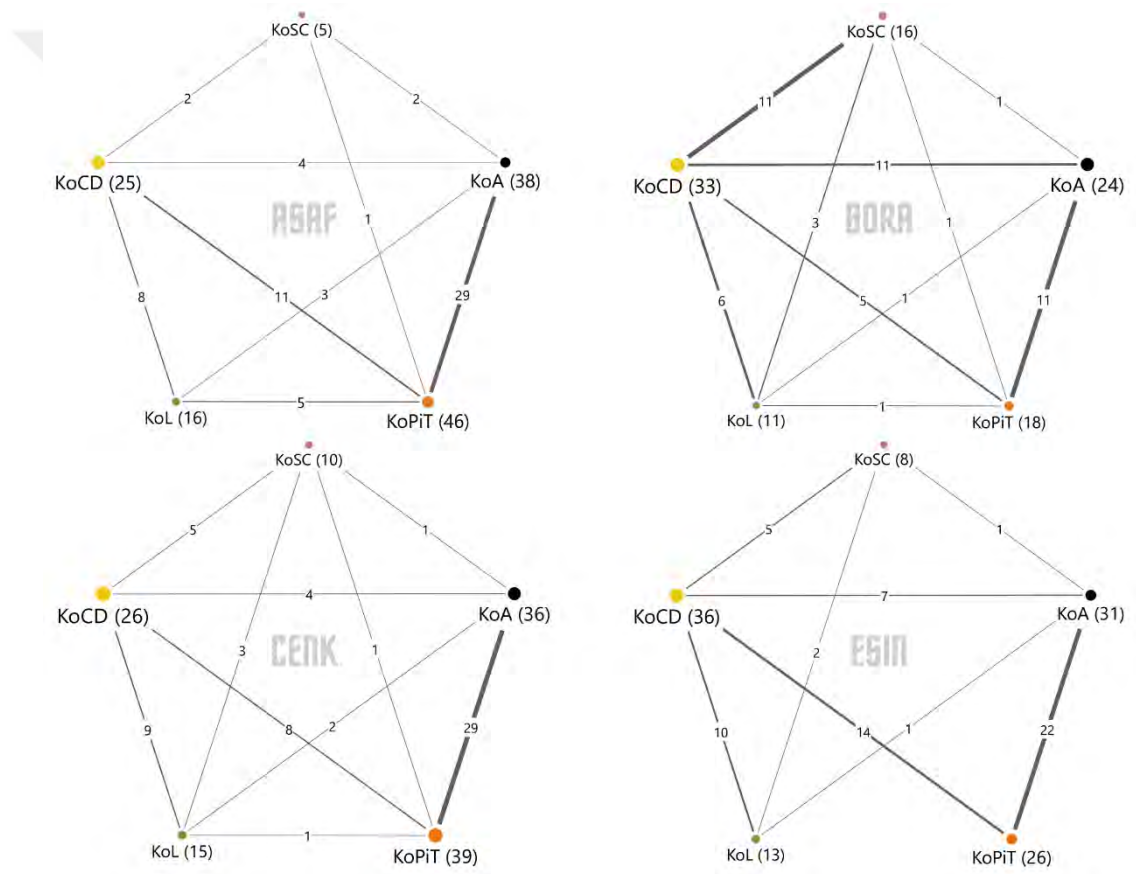


Figure 24. TPACK-P maps of each teacher

Based on these similarities and differences along with the deep analysis of the findings, the following assertions were yielded:

1. The prevalence of strong interplays between KoPiT and KoA underscores the

critical importance of formative assessment in influencing teaching practices.

2. The distinctive layout of each teacher's TPACK-P map highlights the unique nature of TPACK, emphasizing that no two teachers have the same arrangement of components.
3. The consistent emphasis on assessment across all teachers' TPACK-P maps suggests an overarching trend of assessment-focused technology integration.
4. The limited interplays involving KoSC in teachers' TPACK-P maps point to an underutilized potential for enhancing subject content delivery with ICT.
5. The dynamic nature of TPACK is evident in the variations observed across the teachers' TPACK-P maps, reflecting the adaptability of this framework to accommodate individual teaching contexts and preferences.

In conclusion, this section provided a comprehensive analysis of the TPACK-P maps of Asaf, Bora, Cenk, and Esin. Based on careful examination of each teacher's map, distinct features and commonalities in their approaches to technology integration into teaching practices were identified. The findings yielded of several key assertions that shed light on the complex nature of TPACK. Fundamentally, the assertions can roughly be summarized as influential role of assessment in teaching practices, the uniqueness of each teacher's TPACK-P map, the trend of assessment-focused technology integration, underutilized potential subject content delivery, and the dynamic nature of TPACK. The subsequent discussion chapter will provide a detailed exploration and analysis of these assertions.

CHAPTER 5

DISCUSSIONS, CONCLUSIONS AND IMPLICATIONS

This chapter is dedicated to unraveling the findings on teachers' TPACK-P proficiency levels and the intricate interplays among TPACK-P components. Alongside existing literature, these findings were discussed to lead to valuable conclusions and implications.

5.1. TPACK-P Proficiency Levels of In-Service Science Teachers

The present research, following the nature of a multiple case study design, explored TPACK-P proficiency levels of in-service science teachers and discussed it by considering diverse characteristics such as teaching experience, teaching styles, and contextual factors. These TPACK-P proficiency levels exhibited both similarities and differences in teachers' practices related to assessment, planning and designing, and enactment dimensions, along with their subdimensions. The proficiency levels were categorized as lack of use, simple adoption, inclusive application, and reflective application. To recap briefly, lack of use level signifies an inability to effectively use, integrate, and believe in the contribution of ICT tools to teaching practices, resulting in a lack of ICT-related goals and student engagement. In the simple adoption level, teachers adopt basic ICT tools to assess, support instruction, and enhance visualization, often relying on teacher-centered methods, with room for improvement in coherence and technical troubleshooting. Furthermore, the infusive application level indicates that teachers promote inclusive applications by observing students' interactions, utilizing electronic assessments, employing various ICTs to support science learning, facilitating interactive and student-centered methods, and managing ICTs flexibly for inclusive learning environments. Lastly, reflective application level involves the use of LMS for self-learning, comprehensive ICT tools for product design, multiple ICTs for science learning, student-centered strategies, extensive scientific thinking, and skillful technology use for student independent learning.

In the current study, the experienced teachers demonstrated mostly simple adaption proficiency level in terms of assessment, planning and designing, and enactment dimensions, indicating a fundamental grasp of incorporating technology into teaching practices. While this proficiency served as a common baseline across various aspects of TPACK-P for the experienced teachers, it was also observed that none of the teachers including less experienced teachers could reach the highest level of proficiency (reflective application) in three dimensions where technology is seamlessly integrated into teaching practices, fostering independent learning, scientific exploration, and extensive concept building among students. On the other hand, one less-experienced teacher demonstrated reflective application proficiency in certain subdimensions, especially in integrating technology into teaching practices. Notably, less experienced teachers, such as Esin and Cenk, showcased exemplary practices. They effectively used diverse ICTs for interactive learning, implemented formative assessments, and favored a more student-centered instructional style. This proficiency, coupled with a flexible approach to ICT management, set them apart from the broader trend observed among experienced teachers. Esin and Cenk's practices underscore the potential for less experienced teachers to pioneer innovative approaches in integrating technology into teaching practices.

Although Yeh et al. (2015a) underline that increased teaching experience posits stronger TPACK development, this study suggests less experienced teachers exhibit higher proficiency in TPACK-P. This finding may be attributed to early exposure to recent professional development programs emphasizing technology integration during their formative years. Additionally, younger generations of teachers, despite limited teaching experience, have grown up and received training with technology, fostering inherent comfort in incorporating it into their daily lives (Hashim, 2018; Purcell et al., 2013). This comfort extends to their teaching practices, resulting in higher TPACK-P proficiency. Previous studies also suggest that spending a substantial amount of time in the teaching profession (Jang & Tsai, 2013) and employing student-centered teaching approaches (Yeh et al., 2015a) help in developing teachers' TPACK. The current study's findings partially align with these ideas. Since teachers adopting more student-centered teaching approaches were observed to have higher TPACK-P proficiency where they have sufficient knowledge of using ICT with appropriate pedagogical strategies in teaching science subject matter during the processes of

assessing, planning and designing, and enacting science teaching. Thus, while challenging the conventional belief that higher teaching experience leads to higher TPACK proficiency, the present study highlights the pivotal role of student-centered teaching approaches. This accentuates the unique proficiency demonstrated by less experienced teachers who adeptly integrate technology into their student-centered instructional practices.

Transitioning to a dimension-specific analysis, another prominent finding related to teachers' TPACK-P proficiency was the noteworthy distinctions observed in the assessment dimension. While it was observed that these teachers frequently utilized formative assessments, there was a commonality in the basic capacity demonstrated. For instance, Esin and Cenk's proficiency in the assessment domain highlights their potential for elevated and refined assessment practices through the strategic integration of technology. They were observed utilizing out-of-class formative assessments via the EBA platform and assigning design tasks, serving as a testament to their capacity for enhancing assessment strategies when technology is thoughtfully incorporated into teaching practices. In contrast, Asaf and Bora were observed utilizing ICT tools primarily for mostly in-class formative assessment strategies, such as solving exercise questions on the smart board. These variations of proficiencies in assessment dimension might have been influenced by their adaptation of teaching styles and time constraints. Variations in teachers' adaptability and openness to diverse assessment approaches may contribute to differences in TPACK proficiency in assessment dimension. To illustrate, as Asaf and Bora's explicitly emphasized, falling behind the schedule might have caused some teachers to be resistant or reluctant to the idea of using more advanced assessment tools (Loor et al., 2020). Therefore, teachers might have tended to utilize basic or more traditional ICT tools that allow for easy assessment. Similarly, the extensive use of ICT tools during class aligns usually make teachers typically prefer more labor-saving technologies for assessment purposes (Bennett et al., 2017). Accordingly, teachers often lean towards tools that enhance efficiency and reduce the workload associated with assessment tasks. This preference for time-saving technologies reflects a broader inclination within the teaching community to adopt tools that streamline the assessment process, allowing teachers to allocate their time more effectively in supporting student learning. Furthermore, another possible explanation for teachers' lower TPACK-P proficiency in terms of

assessment may be attributed to their lack of knowledge in assessing students with ICT, rather than solely focusing on force and energy topics. This knowledge gap could hinder their ability to fully leverage the potential of technology for diverse and advanced assessment strategies.

Nonetheless, when considered within the TPACK-P framework, it is noteworthy that the use of advanced formative assessment tools by teachers remains relatively limited. These assessments are mostly observed through the use of smart boards, featuring exercise questions such as multiple-choice, matching, sorting, and true-false types. The teachers tend to exhibit a relatively limited integration of these tools, particularly outside the classroom environment. This limited use suggests potential challenges or barriers that may hinder the broader adoption of advanced assessment strategies. As Gipps (2005) emphasizes, electronic assessment construction requires additional knowledge beyond PCK, encompassing skills in multimedia-supported representations, familiarity with assessment channel features, system dependability, and the provision of adaptive feedback. This reinforces the notion that attaining the highest proficiency level in assessment practices involves a multifaceted skill set beyond utilizing basic ICT tools to assess students; none of the teachers in the study reached this advanced level of proficiency.

Since the proficiency of teachers in terms of assessment is not solely estimated in assessment practice, the teachers' efforts in understanding their students' learning needs played a crucial role (Yeh et al., 2015a). According to the findings, the teachers except Esin usually concentrated on using ICTs as probing tools to assess their students' prior knowledge, address potential misconceptions, and facilitate learning progress. Awareness of these learning needs undoubtedly signifies a depth of teachers' knowledge on adapting instructional strategies to individual student requirements. However, these efforts did not automatically translate into high TPACK-P proficiency when considered the established criteria for proficiency levels. The teachers generally tended to utilize basic ICT tools to assess students' needs, especially for teaching facilitation. They often did not mention or commit to additional efforts, such as observing how students interact with various ICT tools, or creating opportunities infused with technology for self-directed student learning. On the other hand, Esin's higher level of proficiency in utilizing ICT tools for assessment is evident in her

comprehensive approach, where she not only assesses students' prior knowledge but also effectively leverages technology to adapt her teaching strategies based on individual student interactions. This may be due to her ability to go beyond conventional ICT use. This suggests a potential area for growth in expanding teachers' proficiency in leveraging technology for more comprehensive and student-centered assessment strategies, particularly paying attention to student-ICT tools interactions.

Another possible reason for lack of proficiency in assessment may be insufficient teacher preparation to instruction. As Yeh et al. (2015a) noted, teachers require more preparation in assessment strategies when integrating ICT into instruction. Compounding this challenge is the significant pressure on science teachers in Turkey, driven by the imperative to ready their students for national exams. This intense focus on exam preparation often leads to a concentration on introducing and solving traditional questions. Unfortunately, it results in a tendency to prioritize these conventional methods over the development of students' scientific thinking abilities through advanced assessment strategies, both inside and outside of the classroom (Diken, 2018; Salehi & Salehi, 2015). This can explain why the teachers may lean towards conventional assessment practices instead of adopting more nuanced approaches that incorporate technology and foster deeper understanding. Their lower proficiency in advanced ICT tools might have been influenced by the prioritization of exam preparation and the limited time available for understanding their students' learning needs and implementing advanced assessment strategies. Thus, it can be concluded that while teachers exhibit a shared commitment to formative assessments, the varying levels of TPACK-P proficiency underscore the need for targeted professional development in advanced ICT tools and student-centered assessment strategies.

Another key finding of the current study is that the planning and design dimension showcases a spectrum of proficiencies among teachers. In essence, the planning and designing processes constitute intricate phases in a teacher's TPACK. These processes involve creating learning experiences that ensure the subject matter is comprehensible to students, demanding a deep understanding of both the subject matter and the educational context (Shulman, 1986). Proficiency in this area necessitates knowledge not only of the subject matter but also an awareness of the science curriculum,

including learning goals, curriculum structure, and teaching strategies (Jones & Moreland, 2004). Additionally, effective planning and designing for science teaching should integrate a critical awareness of ICT affordances (Angeli & Valanides, 2009). This comprehension empowers teachers to strategically incorporate technology, aligning student needs, curriculum requirements, and teaching strategies. According to the findings, teachers exhibited diverse planning approaches, ranging from basic visual enhancements to mainly student-centered strategies. For instance, those teachers who faced difficulties in keeping up with the program schedule were observed to be less able to use advanced ICT representations for fostering scientific thinking and exploration in their classes. In contrast, the remaining teachers demonstrated success in consolidating students' concept understanding and construction in their classes", this sentence seem correct and logical: This diversity underscored the adaptability of teachers in tailoring technology integration to their specific instructional needs and preferences, showcasing a range of proficiency levels among teachers.

One possible reason for this may be a result of their lack of experience in designing technology-based classes. In comparison to newly graduated teachers, experienced teachers are more likely to encounter difficulties in creating impactful learning design ICT representations and require assistance to effectively utilize design support tools (Masterman & Manton, 2011). Moreover, as emphasized by Meagher et al. (2011), it is plausible that teachers might not completely translate their understanding of technology utilization into practice during the planning of their classes. This potential limitation in effectively implementing technology-related knowledge in instructional planning could contribute to the observed lower level of proficiency among experienced teachers, as they may face challenges in fully embracing and incorporating technology into their teaching strategies. This might be due to their more up-to-date pedagogical and technological knowledge compared to when they graduated, as claimed by Koni and Krull (2018). Accordingly, less-experienced teachers regard achieving the established objectives in both short-term and long-term planning as more significant than their experienced counterparts. Furthermore, the data suggests that the limited use of ICT representations might be attributed to contextual factors, such as time constraints. Cakir (2013) highlights that teachers may encounter challenges, including time limitations, classroom management, and hardware-software issues, hindering ICT integration into their classes. According to Asaf and Bora's

interview data, both expressed challenges in adhering to the program schedule, which could potentially affect their utilization of advanced ICT representations for fostering scientific thinking and exploration in their classes. However, despite these constraints, their primary focus on using ICT representations was directed towards enhancing motivation and visualization. Thus, this diversity in planning approaches, influenced by experience, technological knowledge, and contextual constraints, underscores the need for a nuanced understanding of teachers' TPACK in the planning and design dimension.

Notably, it was concluded from the findings of the study that the diverse proficiency levels observed in teachers' TPACK-P within the enactment dimension call for a more nuanced understanding of the factors influencing technological integration capabilities. For instance, the observed proficiency levels challenge conventional expectations, particularly the assumption that more experienced teachers inherently possess higher enactment proficiency within the TPACK-P framework (Hamid et al., 2012). With greater teaching experience, Asaf and Bora tend to adopt more verbal and visual instruction in ICT guidance for students. In contrast, Cenk and Esin, despite being relatively less experienced, excel in encouraging students to learn through ICT and conceptualize force and energy topics with ICT implementations. Recalling that TPACK is an experience-based phenomenon, one might anticipate that experienced teachers would enact ICT-based instructions more skillfully than novice teachers (Yeh et al., 2015b). However, the observed proficiency levels of the teachers participated to this study suggest a nuanced relationship between teaching experience and ICT integration capabilities. This prompts consideration of other factors, including the inherent adaptability of novice teachers like Cenk and Esin, who, due to their younger age, might naturally be more acquainted with ICT tools. Age and familiarity with ICT tools may contribute to the nuanced proficiency levels observed in the enactment dimension. This necessitates a more nuanced understanding of the factors influencing technological integration capabilities among teachers. The study highlights the need to go beyond the traditional belief that experience alone determines higher TPACK-P proficiency, emphasizing the significance of considering additional factors in this complex relationship. The diverse proficiency levels among teachers prompt a reconsideration of conventional views on the interplay of teaching experience and ICT integration capabilities, urging further exploration into the nuanced dynamics that

shape teachers' proficiency within the enactment dimension.

Further evidence sheds light on explaining the diversity in teachers' TPACK-P within the enactment domain. The TPACK-P framework emphasizes the importance of teachers being well-prepared to handle any technical challenges that may arise during their lessons, evaluating their proficiency based on their ability to navigate these issues. For instance, Asaf and Cenk demonstrated simple adoption proficiency level referring to a basic skill level in resolving technical problems during class, often resorting to traditional, non-ICT teaching methods when faced with challenges. This highlights their limited competence in effectively addressing technical issues. On the other hand, Bora's proficiency level tends toward infusive application, despite occasional reliance on simple solutions resulting in fallbacks to traditional teaching methods. This finding is intriguing, given Bora's role as a mentor IT teacher with extensive technology literacy, frequently troubleshooting various technology-based hardware and software issues. However, it became evident that he could not consistently demonstrate proficiency in continuing the class without interruption in struggling with technical issues during the class. What he lacked was the absence of backup plans when faced with technical issues. This implies that possessing extensive technology literacy alone does not guarantee proficiency as emphasized by Erduran and Ince (2018). Previous research has indicated that teachers may face challenges in technology-based instruction, attributed to factors such as inadequate technology infrastructure, lack of motivation, and insufficient administrative support (Habibu et al., 2012). This acknowledgment opens avenues for future research to delve deeper into the interplay between these external challenges and teachers' TPACK-P proficiency, impacting their overall ability to integrate technology effectively into their teaching practices.

Furthermore, the inclusion of the 'Infusing ICTs into Teaching Contexts' subdimension within the enactment dimension in this study constitutes a valuable contribution. The criteria employed to assess proficiency levels, ranging from a belief in no contribution of ICT to the skillful use of technology for supporting student independent learning, provide a comprehensive framework. By examining these dimensions, this study contributes to a more holistic understanding of teachers' TPACK-P, offering valuable insights for teacher education and professional

development programs aiming to enhance teachers' proficiency in infusing ICTs into teaching contexts. For instance, Cenk enhanced the overall teaching experience through the integration of visually appealing and interactive ICT tools to assist students' learning. Likewise, Esin employed ICTs flexibly and selectively to enhance her students' understanding of scientific concepts. Their proficiency levels were comparable concerning knowledge and practices related to ICT integration, as identified by Yeh et al. (2015a), who classified them as technology-infusive teachers. In earlier studies, such competency of teachers was often considered as a catalyst to enhance teacher-student dynamics leading to not only better learning (Elsayed & Puteh-Behak, 2017) but also greater student motivation (Roy, 2019). Therefore, teachers' proficiency in infusing ICT into their classes underscores their adeptness at integrating technology to foster an environment where students actively participate and benefit from ICT-enhanced instruction, contributing positively to their TPACK-P in their teaching practices. This alignment between teachers' proficiency in incorporating ICT and the improvement of teacher-student dynamics, learning outcomes, and student motivation emphasizes the integral role of technological integration in enhancing overall pedagogical effectiveness. As teachers adeptly infuse ICT into their instructional strategies, they not only cultivate a more engaging and interactive learning environment but also develop a comprehensive TPACK-P that aligns with the evolving needs of contemporary education. This, in turn, prepares students for the challenges of a technology-driven world, fostering a holistic educational experience that goes beyond traditional teaching approaches.

5.2. Nature of Interactions among TPACK-P Components

While revealing the TPACK-P proficiency levels of in-service science teachers, this research also explored the interplays among the teachers' TPACK-P components by depicting TPACK-P maps for each teacher. These maps underwent careful examination, revealing distinct features and commonalities in the teachers' approaches to technology integration into teaching practices. The findings led to the identification of five key assertions that illuminate the complex nature of TPACK. Each of these assertions is discussed in the relevant literature in the following sections.

5.2.1. The prevalence of strong interplays between KoPiT and KoA underscores the critical importance of assessment in influencing teaching practices

Based on the collected data and the TPACK-P maps of the in-service science teachers, it was observed that the highest interplays occurred between KoPiT and KoA in each teacher. Such interplays involve teachers' knowledge in addressing challenges related to ICT use, their instructional management skills tailored to student needs, and their ability to guide students effectively in using technology for learning when utilizing technology for designing and conducting science assessments. Therefore, this emphasizes the crucial connection between teachers' proficiency in technological problem-solving, instructional management, and guiding students in the context of utilizing technology for science assessments.

The intricate interaction between KoPiT and KoA reveals nuanced strategies employed by teachers to address ICT-related challenges, tailor instructions to student needs, and guide students in effectively utilizing technology for science assessments. The symbiotic relationship is exemplified in specific cases, such as Asaf's adept use of in-class formative assessments and Cenk's strategic incorporation of digital platforms for out-of-class formative assessments. Consequently, these insights highlight the intricate dynamics of KoPiT-KoA interactions and their significance in fostering effective technology integration in science education. For instance, Asaf's TPACK episodes underline the symbiotic relationship between KoPiT and KoA, particularly evident in his adept utilization of in-class formative assessments. This integration not only gauged student understanding but also showcased Asaf's expertise in guiding students effectively in technology-enhanced learning. Similarly, Cenk's teaching practices showcase a dynamic interplay between KoPiT and KoA, particularly evident in his active encouragement of students to utilize ICT tools during in-class formative assessments. Cenk's strategic use of ranking questions effectively engages students in technology-enhanced learning experiences. These findings contribute to the existing literature, suggesting that science teachers' ICT proficiency in assessing students not only facilitates student engagement in technology-infused teaching, as explored by Ali (2020) and Herbert (2017), but is also integral to gauging and enhancing student engagement in science education. One reason for the observed prominence of this synergy, particularly the high interactions between KoA and KoPiT among science

teachers' TPACK-P components, may be teachers' inclination to employ more time-efficient technologies in formative assessment processes (Bennett et al., 2017). This inclination makes the integration of ICT into their teaching practices more accessible, particularly in solving exercise questions.

Notably, the bidirectional interplay extends beyond in-class assessments to out-of-class formative assessments, with teachers like Cenk leveraging digital platforms for homework assignments. Likewise, Esin's awareness of the advantages and disadvantages of relying on EBA for homework assignments showcases a nuanced consideration of KoPiT and KoA. Her balanced approach to digital homework further underscores the nuanced consideration of KoPiT and KoA in fostering equity in learning opportunities. These findings resonate with the broader literature on the role of technology in formative assessments and teaching practices. While the debate surrounding the effectiveness of online homework persists (Dodson, 2014), studies such as those conducted by Doorn et al. (2010) and Efimova (2021) emphasize the potential of digital homework to enhance the overall teaching and learning experience. The bidirectional interplay observed in Cenk's and Esin's practices aligns with the notion that formative assessments, especially those facilitated by digital tools, can create a symbiotic relationship between guiding students in learning through ICT and conducting assessments. This reciprocal connection contributes to a more comprehensive understanding of how technology integration during out-class formative assessment influences teaching practices, offering valuable insights for teachers seeking effective strategies in the digital age.

Furthermore, the intentional use of design-based assessment tasks highlights how KoA informs their KoPiT. The design of assignments promoting ICT tool utilization aligns with their broader goal of enhancing students' ICT literacy. By guiding students on assignments based on product development, the teachers' KoA directly contributes to his pedagogical strategies involving technology use of students (KoPiT). These findings resonate with the broader literature on the effectiveness of design-based tasks. For instance, Kearney et al. (2006) and Felix (2015) both found that such tasks not only enhance teachers' PCK development, but also improving their students' ICT competencies. Guiding students to use relevant ICT tools in learning science topics may elevate their digital literacy skills, preparing them for the demands of the modern

world. These insights underscore the pivotal role of assessment, particularly through design-based tasks, in shaping teaching practices and enhancing technology integration in science education. Consequently, the identified prevalence of these interplays further reinforces the centrality of assessment in shaping teaching practices and highlights its instrumental role in preparing students for the digital landscape of the 21st century.

The absence of a prominent interplay between addressing challenges related to ICT use and instructional management skills tailored to student needs during assessments is noted in the study. The operational definition of the KoPiT-KoA interplay encompassed these elements, reflecting initial expectations regarding the multifaceted nature of technology integration in science education. However, upon closer examination of the collected data, it became evident that the interactions primarily centered around guiding students effectively in using technology for learning and assessments. This observation prompts a reevaluation of assumptions implicit in the operational definition and underscores the need for a nuanced understanding of the dynamic interplays within the TPACK-P framework. The assumption that addressing challenges related to ICT use and tailoring instructional management skills to student needs would be equally emphasized in the interplay between KoPiT and KoA needs to be critically revisited. Possible explanations for the observed pattern may include the specific instructional context, teacher preferences, or the nature of the assessed tasks. It is crucial for future research to delve deeper into the factors influencing the dynamics of KoPiT, especially regarding addressing ICT challenges and tailoring instructional management to student needs during assessments, to provide a more comprehensive understanding of technology integration in science education.

5.2.2. The distinctive layout of each teacher's TPACK-P map highlights the unique nature of TPACK, emphasizing that no two teachers have the same arrangement of components

The distinctive layout of each teacher's TPACK-P map underscores the unique nature of TPACK, emphasizing the individualized arrangement of components. The examination of TPACK-P maps for each teacher reveals diversity in the layout and arrangement of components, highlighting the uniqueness of each teacher's TPACK-P.

Represented as a pentagon with corners symbolizing knowledge components, each TPACK-P map unravels intricate interplays and preferences that shape the integration of technology in science education, particularly force and motion topics.

In exploring the TPACK-P maps, it is evident that no two teachers share the same configuration of components. The thickness of lines connecting each corner signifies the frequency of interactions, offering insights into the prominence of specific interplays within individual TPACK-P frameworks. As an illustration, Asaf's TPACK-P map showcases a strong interplay between KoA and KoPiT, emphasizing his adept guidance on ICT use during student assessments. In contrast, Bora's map displays comprehensive connectivity, with a particular emphasis on KoCD-KoA and KoCD-KoPiT interplays, highlighting his proficiency in curriculum design and assessment practices. Esin's map, on the other hand, exhibits a different layout, emphasizing the importance of planning and designing in technology-based science teaching. This divergence may be influenced by factors such as teachers' teaching styles, preferences, experiences, and adaptability to technology. Notably, Bora and Cenk appear to have developed a more comprehensive and well-balanced TPACK-P, indicative of their expertise in integrating technology across various aspects of teaching. In contrast, Asaf and Esin seem to adopt more focused approaches, with specific interplays receiving more attention, reflecting their distinct teaching styles and preferences.

The distinct features of TPACK-P maps align with the idiosyncratic nature of PCK. Understanding this alignment provides valuable insights into the complex dynamics of teacher knowledge, particularly in the application of technology for effective teaching and learning in the science domain. PCK, recognized for its topic-specific and context-dependent characteristics, is intricately tied to subject matter and teaching context (Van Driel & Berry, 2012; Park & Chen, 2012). PCK is a unique form of knowledge that teachers possess, distinct from content knowledge (Rollnick, 2017). This knowledge is developed over time and through experience, and is influenced by the teaching context, content, and experience (Van Driel & Berry, 2010). It is a specialized knowledge that combines deep content and pedagogical knowledge, and is crucial for effective teaching (Buchholz et al., 2013). Therefore, this research reinforces the idea that TPACK-P displays unique characteristics similar to the

distinctive nature of PCK. It provides insight into the complex dynamics of teacher knowledge and how it is applied in the integration of technology for effective teaching and learning. Consequently, the nuanced examination of TPACK-P layouts in this study resonates with the established understanding of PCK's idiosyncrasy, highlighting the intricate relationships between teacher knowledge, content, and instructional context.

Notably, certain interplays such as KoL-KoSC and KoPiT-KoSC, appear relatively sparse or none across all teachers, indicating limited integration or influence between these components in the context of TPACK-P framework. These unexplored connections prompt further considerations about the specific instructional context, teacher preferences, or the nature of assessed tasks that may influence the dynamics of TPACK-P frameworks. The distinctive layouts found in each teacher's TPACK-P map underscore the inherent uniqueness of TPACK, emphasizing the absence of identical configurations among teachers. This uniqueness extends beyond the immediate context, linking to broader educational concepts. Insights from Mavhunga and Rollnick (2013) shed light on the topic-specific nature of PCK, especially in the realm of teacher education programs. The emphasis lies in recognizing the distinct demands posed by various subjects and tailoring PCK development to address the intricacies of each content area. Similarly, Tuithof (2017) adds another layer by highlighting the role of teaching orientation in shaping PCK, indicating that individual teachers' beliefs, approaches, and orientations towards teaching contribute significantly to the development and application of their PCK. This connection to PCK becomes particularly relevant when examining the distinct features of each case in this study, as these features could potentially influence technology integration and TPACK-P.

5.2.3. The consistent emphasis on assessment across all teachers' TPACK-P maps suggests an overarching trend of assessment-focused technology integration

In the exploration of teachers' TPACK-P maps, the critical importance of specific interactions, particularly between KoPiT and KoA, was illuminated in the subsection 5.2.1. The significant influence of assessment practices on teaching strategies was underscored, revealing the nuanced nature of technology integration in science

education. Shifting the focus to a broader perspective, a consistent emphasis on assessment across all teachers' TPACK-P maps is observed. This overarching trend suggests a collective inclination towards assessment-focused technology integration, marking a distinct yet interconnected aspect of how technology is incorporated into teaching practices by teachers. As this exploration unfolds, it becomes crucial to distinguish this overarching trend from the specific interactions highlighted earlier, elucidating how both contribute to the intricate fabric of teachers' TPACK-P and shape the landscape of contemporary science education.

The teachers' TPACK-P maps consistently revealed KoA as one of the most interacted knowledge components. These formative assessment practices align well with the dynamic and evolving nature of science education, providing teachers with valuable insights into students' understanding of science concepts (Dini et al., 2020; Lopez-Lozano et al., 2018). Both observations and interviews underscored that the teachers consistently leveraged digital resources for assessing their students. The findings demonstrated that KoA stood out as a component interacting with all other components, including KoCD. While assessments encompassed pre-assessments and formative assessments, the teachers predominantly employed ICT tools for formative assessments. For example, all teachers engaged students with numerous exercise questions during and after teaching each subtopic within the force and energy topics. These questions ranged from multiple-choice and ranking to true-false and fill-in-the-blank formats. Additionally, teachers assigned various achievement tests as online homework for students. These examples indicate a pronounced emphasis on formative assessment in teachers' practices. While previous studies did not explicitly emphasize a clear tendency among teachers to use technology in assessment processes (McKnight et al., 2016; Webb & Gibson, 2015), the current study reveals that teachers are notably inclined to utilize technology particularly for assessment purposes. Particularly in regions where national exams take precedence over learning, teachers tend to incorporate more questions into their teaching strategies to prepare students for these exams (Çetin & Ünsal, 2019). Therefore, the consistent emphasis on formative assessment in science education, as indicated by teachers' pervasive use of technology, reflects a broader pedagogical strategy. This strategy aligns with the prevalent trend among teachers, especially in contexts where high-stakes examinations dominate the educational landscape, underscoring the dynamic interplay between technology

integration and the evolving priorities of science education.

Moreover, teachers such as Esin demonstrated a versatile approach by incorporating educational games (KoCD) into the classroom through platforms like learningapps.org. These innovative teaching methods not only added an element of fun but also served as effective in-class formative assessments (KoA). The integration of educational games allowed students to actively participate and demonstrate their understanding of various concepts, fostering a dynamic and engaging learning environment. Similarly, Asaf took a creative approach by incorporating a science-lesson adapted version of the 'Who Wants to Be a Millionaire' game. This activity involved collaborative problem-solving with multiple-choice questions, contributing not only to in-class formative assessments (KoA) but also enhancing students' enjoyment and engagement (KoL). The utilization of educational games in Esin's and Asaf's teaching practices highlights how the teachers strategically adapted their assessment practices to integrate enjoyable and interactive elements into their classes. Beyond traditional assessment methods, incorporating educational games aligns with contemporary pedagogical approaches that recognize the importance of engaging students in diverse ways to enhance learning outcomes. Recent studies further support the positive impact of ICT-based assessment in educational games on both learning outcomes and assessment processes. For instance, Juliantari et al. (2018) and Hafez (2022) emphasize the potential of these games to not only improve student learning but also facilitate stress and anxiety associated with assessments. This aligns with the observed practices of teachers like Esin and Asaf, showcasing a broader trend in leveraging technology to create a more inclusive, engaging, and effective assessment environment in science education. Therefore, these findings underscore the transformative potential of technology-integrated assessments in promoting a positive and constructive learning experience for students, reinforcing the prevalent movement towards assessment-focused technology integration in science education.

Considering this transformative potential of technology-integrated assessments, it becomes crucial to discuss the broader landscape of educational outcomes. Relating this finding to the importance of assessment in educational outcomes brings attention to the integral role technology plays in shaping not only what and how students learn but also how their understanding is evaluated and measured. This alignment with

contemporary educational priorities emphasizes the dynamic interplay between technology integration and the evolving landscape of science education (Pellegrino & Quellmalz, 2010). In essence, the incorporation of technology into assessment practices is not merely an augmentation of traditional methods; rather, it represents a fundamental shift in the educational paradigm (Cheremisin et al., 2022; Zovko, 2016). It goes beyond influencing the content of learning, extending to the very methodologies employed in teaching and learning.

Furthermore, earlier research also underlines the changing dynamics in teachers' priorities. Yeh et al. (2015b) found that teachers often prioritize curriculum design over assessment or practical teaching knowledge, indicating a broader shift in instructional focus. Russell et al. (2003) noted that teachers predominantly use technology for preparation and communication rather than for direct instructional delivery or assigning learning activities. This resonates with the findings of the present study, highlighting the multifaceted roles technology assumes in education, particularly in the preparatory and communicative aspects. Moreover, the evolving trend in science education is notable, as Paje et al. (2021) suggest a growing reliance on technology for science instruction, including assessment purposes. Agommuoh et al. (2021) contributes to this discourse by pointing out that science teachers, as a general practice, are trained in and actively use ICTs in their teaching. Consequently, the collective inclination towards assessment-focused technology integration, as evident in the current study, emphasizes the transformative impact of technology on shaping educational practices and priorities.

5.2.4. The limited interplays involving KoSC in teachers' TPACK-P maps point to an underutilized potential for enhancing subject content delivery with ICT

The limited interplays involving the KoSC component in teachers' TPACK-P maps point to an underutilized potential for enhancing subject content delivery with ICT. KoSC, crucial for proficiently employing technology to deliver challenging science content, exhibits limited interactions across teachers, emphasizing a gap in intentionally integrating ICT tools for content delivery. The findings revealed that KoSC as the least interacted component in each teacher's TPACK-P map, except for

Bora, whose KoSC ranks second after KoL. Moreover, the interaction between KoSC and other components were either weak or nonexistent. In line with its operational definition within the TPACK-P framework, KoSC pertains to a teacher's proficiency in utilizing ICT to deliver challenging science content. This encompasses the skill of using technology to enhance comprehension and the discernment to choose suitable ICT tools for content delivery. It is crucial to note that KoSC does not involve just the delivery of science content but rather the intentional selection of ICT tools to support student learning. Accordingly, KoSC does not imply purely delivering science content; instead, it encompasses a teacher's deliberate selection of ICT tools to facilitate students' learning and an awareness of which ICT tool fits with the delivery of related science content. The significant scarcity of interactions involving the KoSC component across teachers' TPACK-P maps suggests that, except for those possessing more advanced knowledge in technology, teachers generally do not prioritize utilizing ICT to enhance comprehension or intentionally selecting suitable ICT tools for content delivery in their technology integration practices. The varying degrees of technological expertise among teachers, including Bora as an IT mentor teacher, may influence their ability to effectively connect subject content knowledge with technology integration practices.

Integrating technology into science education is a multifaceted process requiring a deep understanding of both the subject matter and the technological tools in use (Pringle et al., 2015). The inherent complexity and abstract nature of scientific concepts make it challenging to convey them effectively through digital tools alone. For instance, Cenk emphasized that topics like atoms are challenging for students to grasp without visual aids. Similarly, Esin stressed the need for animations or videos to illustrate complex processes like DNA replication. Although these examples extend beyond the force and energy unit, they highlight the essential role of technology in understanding complex scientific phenomena. Moreover, the use of an e-experiment in one of Cenk's classes to elucidate the relationship between applied force and work done exemplifies how technology aids in visualizing abstract scientific concepts. However, it is crucial to note that these instances were not universally present across all TPACK episodes. The lack of explicit examples in teachers' use of convenient teaching approaches in challenging science topics with appropriate ICT tools contributes to the scarcity of interactions between KoSC and KoCD. Aligning with

earlier studies (Harish et al., 2013; Magnusson et al., 1999) that highlight a strong interplay between KoSC and KoCD as pivotal in effective science teaching, the current study points to the observed variability in the application of teaching approaches and technology. This variability may contribute to the scarcity of interactions in KoSC, as not every TPACK episode provides opportunities for such integrations.

Furthermore, when exploring the interactions between KoSC and KoA, a similar pattern emerges. This brings to light the challenges teachers face in integrating assessment strategies with their subject content knowledge. The constrained integration may be attributed to teachers' varying levels of comfort and familiarity with assessment technologies. Teachers more accustomed to traditional assessment methods, such as multiple-choice questions, might hesitate to explore and adopt ICT tools for formative assessments, like short answer word clouds or concept mapping. In doing so, they may unintentionally overlook or struggle to integrate a diverse array of ICT tools suitable for the specific content they are teaching. Furthermore, standardized testing requirements, such as the national exam format, could impose constraints on the flexibility of content-focused integration into assessments. Consequently, this may lead to a perceived lack of confidence and competence among teachers in effectively incorporating ICT tools into science assessments (Murphy & Smith, 2012). This lack of confidence might influence their choices regarding the incorporation of ICT tools, reflecting the intricate interplay between subject content knowledge and assessment strategies. The limited interplay observed between KoSC and KoA underscores the nuanced challenges teachers face in seamlessly integrating subject content knowledge and assessment strategies, revealing the need for targeted support and professional development to enhance the effective use of ICT tools in science education.

Similarly, the interplays between KoPiT and KoSC were notably scarce in the TPACK-P maps of the observed teachers. While Esin's encouragement for students to engage in interactive experiments and discussions using ICT tools exemplifies effective content delivery, such instances were relatively limited in the overall dataset. The shortage of interactions between KoSC and KoPiT may stem from teachers' varying levels of proficiency in applying pedagogical strategies related to ICT. The results of the present study suggest that if teachers are not adequately trained in the pedagogy of ICT, they might encounter challenges in seamlessly integrating digital

tools into their science content delivery. This aligns with the findings of Helppolainen and Aksela (2015) and Kafyulilo et al. (2015), both of whom emphasize the crucial need for TPACK training to enable effective ICT use in the classroom. Therefore, the limited interplay between KoSC and KoPiT underscores the importance of providing comprehensive training to teachers, facilitating the seamless integration of pedagogical strategies with ICT tools in science education.

5.2.5. The dynamic nature of TPACK is evident in the variations observed across the teachers' TPACK-P maps, reflecting the adaptability of this framework to accommodate individual teaching contexts and preferences

The dynamic nature of TPACK-P is vividly illustrated through the observed variations across the teachers' TPACK-P maps, revealing the adaptability of this framework to diverse teaching contexts and individual preferences as highlighted by Koh et al. (2014). Emphasizing its strength in accommodating the unique nuances of educators' approaches, Bibi and Khan (2016) further highlight how this adaptability enhances the effectiveness of the TPACK framework in diverse educational settings. The strength of TPACK lies in its inherent flexibility, allowing teachers to tailor the integration of their knowledge components of TPACK-P according to their unique instructional situations. For instance, Cenk demonstrated a nuanced application of TPACK-P by utilizing the EBA platform to conduct a virtual experiment exploring the relationship between applied force and work done, incorporating hypothesis testing to elucidate complex scientific concepts. This approach aligns seamlessly with pedagogical strategies that encourage student-driven exploration and understanding. Esin, on the other hand, strategically incorporated hands-on experimentation with an interactive experiment to develop scientific inquiry skills. She seemed to know how to apply these skills in the context of ICT-infused learning, reflecting a personalized approach to technology integration. In contrast, Asaf utilized a drag-and-drop experiment related to weight with teacher-led teaching approach. These examples collectively showcase the TPACK-P framework's strength in accommodating diverse teaching styles and preferences, fostering a more effective and tailored integration of technology in science education. The influence of teaching styles on how teachers shape their TPACK is supported by previous studies, indicating that more student-centered teaching approaches point to a stronger TPACK (Efilti & Coklar, 2013; Yeh et al.,

2015a). Therefore, the findings from this research suggest that the TPACK-P framework well reflects the dynamic nature of teachers, particularly in light of the stronger indication of more student-centered teaching approaches within TPACK.

The adaptability of TPACK is not only a reflection of individualized teaching styles but also a powerful tool for responding to the evolving needs of students and the changing landscape of educational technology. For instance, Esin adeptly adjusted her TPACK framework to include online platforms, recognizing the paramount importance of fostering digital skills in an increasingly interconnected world. An exemplary instance is her utilization of an interactive virtual classroom presentation in her class, meticulously prepared during the online education. Esin showcased this resource to her students in one of her classes by emphasizing its utility, and further expressed her intention to make it accessible on the EBA platform for the benefit of her students. This strategic adaptation not only highlights the integration of technology for collaborative learning but also showcases the innovative reuse of resources to enhance the virtual classroom experience. Instances like these illustrate the versatility of TPACK, allowing teachers to creatively repurpose tools and materials to suit their instructional needs (Redmond, 2015). Moreover, this adaptability seems to be a key feature that empowers teachers to navigate the rapidly changing world of educational technology, fostering a dynamic and responsive approach to integrating technology in education.

In this context, the concept of teacher agency comes to the forefront. Teacher agency involves teachers' proactive ability to make professional decisions, influence events, and shape their own work and studies within the educational setting (Priestley et al., 2012; Vahasantanen, 2015). It plays a pivotal role in the dynamic relationship between TPACK and instructional practices (Albion, 2018; Priestley et al., 2015; Voogt et al., 2018). Esin's proactive adjustment of her TPACK showcases teacher agency in action, demonstrating a teacher's ability to deliberately decide on technology integration based on their expertise, context, and the specific needs of their students. This sense of agency empowers teachers not only to adapt to emerging technologies but also to actively shape their teaching practices and curricula. It reflects a conscious effort to navigate the dynamic landscape of educational technology, aligning with the broader narrative of teachers as active agents in their professional development and the

application of technology in their classrooms. The symbiotic relationship between TPACK and teacher agency, where teacher agency influences the development and application of TPACK and, in turn, TPACK is shaped by teachers' agency in integrating technology into their teaching practice (Albion & Tondeur, 2018), highlight the crucial role teachers play in shaping the trajectory of technology integration in education (Kristiawan et al., 2022).

Furthermore, exploring the participants' beliefs and philosophies regarding technology's role in education adds another layer to the understanding of TPACK dynamics, shedding light on the potential role of teacher agency in shaping these dynamics. For example, Bora's pragmatic approach, particularly his preference for ready-made educational content like digital textbooks, reflects a distinct technological philosophy. This philosophy is evident in various features of Bora's TPACK, shaping his instructional decisions and interactions with technology. During a lesson on energy transformation, Bora strategically employs the Antropi Teach software, showcasing his pragmatic philosophy in the application of pre-existing technological tools for in-class formative. This brief snapshot of Bora's TPACK highlights the dynamic nature of his technological integration, showcasing adaptability to specific educational needs. In a similar vein, Asaf's teaching practices offer another perspective on the dynamic nature of TPACK. His emphasis on using an educational game called the Millionaire illustrates an interplay between KoCD and KoA. Asaf incorporates the Millionaire game into the classroom, integrating it into in-class formative assessment strategies. Ultimately, this pedagogical choice not only fosters an engaging and enjoyable learning experience for students but also serves as a testament to teachers' proactive curriculum design and assessment strategy. Teachers' intentional selection of innovative instructional methods showcases the agency that teachers wield in shaping the integration of technology into their teaching practices. Rather than adhering to conventional approaches, teachers' proactive stance exemplifies the autonomy teachers possess to choose, design, and implement technology-infused methods that align with their pedagogical objectives and cater to the specific needs of their students. Thus, the illustration of combining curriculum design with assessment strategies in science education not only highlights the positive impact of such an approach but also emphasize the symbiotic relationship between teacher agency and the dynamic nature of TPACK.

To enrich this discussion further, drawing upon relevant research that explores the symbiotic relationship between teachers' technological philosophies, instructional practices, and the evolving landscape of TPACK can provide deeper insights. Ihde (1993) posits that when a technology stabilizes in its use in a specific context, it may direct how people experience and interpret the world. Additionally, Luke and Britten (2007) and Kopcha et al. (2020) emphasize the pivotal role of teachers' technology training experiences in shaping their beliefs toward technology and expanding their knowledge of available technologies. These considerations are particularly relevant in the realm of science education, where technological advancements play a crucial role in curriculum design, laboratory practices, and student engagement. Furthermore, Ahn's (2020) exploration of the dynamic nature of TPACK adds another layer to our understanding, emphasizing how TPACK evolves over time as teachers accumulate experience and knowledge in utilizing technology in the classroom. In the context of science education, where the integration of technology can greatly enhance the exploration and understanding of scientific concepts, this dynamic evolution becomes even more pronounced. Ahn's emphasis on the importance of ongoing professional development aligns with the ever-changing nature of science and technology, highlighting the need for educators to stay abreast of advancements and effectively integrate them into their teaching practices. Integrating insights from these studies would contribute to a more comprehensive understanding of how teachers' beliefs, shaped by their technological philosophies and instructional practices, contribute to the dynamic integration of technology in science education.

5.3. Connecting the dots between TPACK-P proficiency and interplays among the TPACK-P components

This study embarks on a dual exploration, delving into the proficiency levels of in-service science teachers' TPACK-P in teaching force and energy topics while unraveling the intricate interplays among its five components. Although distinct, these two research questions intricately weave into each other, providing a comprehensive understanding of the dynamics at play in technology-enhanced science teaching.

The observed patterns in interplays among TPACK-P components, when viewed alongside teachers' proficiency levels, reveal a complex landscape with subtle

relationships. According to the results of the present study, a teacher's high level of proficiency may not necessarily indicate that the teacher possesses a more integrated TPACK-P. In other words, proficiency alone may not be a reliable indicator of the depth or comprehensiveness of a teacher's TPACK-P. To illustrate such nuanced link between proficiency levels and interplays, Asaf's case can be examined. Despite Asaf demonstrating a relatively lower proficiency (simple adoption) in the assessment dimension, the number of interplays related to KoA was the second-highest component. Similarly, despite her relatively high proficiency (infusive application) in all dimensions, the number of interplays in the KoPiT dimension was lower than in KoA and KoCD for Esin. This implies that a higher proficiency level in assessment does not necessarily result in a higher number of discernable interplays within the TPACK-P dimension. Contrary to the findings of this study, prior research has suggested a close connection between proficiency levels and a more integrated TPACK. For instance, Aydin-Gunbatar et al. (2023) reported that as teachers' TPACK-P proficiency advances, the integrations depicted in their TPACK-P maps become more intricate and diverse. This intricacy prompts a deeper exploration into the factors influencing the relationship between proficiency levels and interplays (Celik et al., 2014; Wardoyo et al., 2021). Furthermore, considering TPACK's origin rooted in PCK, literature on PCK supports a similar link between proficiency and the interplay among knowledge components. Earlier studies (Aydin et al., 2015; Mavhunga, 2020; Şen et al., 2022) consistently emphasize the integral link between teachers' proficiency levels and the nuanced interactions among TPACK components. These findings resonate with the broader understanding in the literature, suggesting a connection between teachers' proficiency levels and the intricate dynamics within the TPACK-P framework. While these studies provide valuable insights into the general relationship between proficiency and TPACK, the present research delves into the specific context of science teachers' TPACK-P, offering a nuanced exploration of how proficiency may interact with the interplays among its components. Thus, a plausible interpretation arises, suggesting that proficiency levels may not uniformly impact all interplays; certain dimensions might be more responsive to advancements in proficiency than others. The specificity and individuality observed in connections challenge the direct link between overall proficiency and the intricacy of interplays. Moreover, another noteworthy aspect in the study pertains to the quality of interactions

despite a lower quantity. Despite some teachers exhibiting fewer interactions among components, the study observed that these interactions demonstrated higher quality. This implies a role for TPACK-P proficiency in shaping the depth and effectiveness of interplays. For instance, in Esin's case, where interactions between KoA and KoPiT were fewer than Asaf, her high proficiency level became evident through a more strategic and purposeful integration of technology into pedagogical practices. Esin's adeptness in encouraging active student involvement during in-class assessments and addressing potential drawbacks related to technology-driven homework assignments showcased not only the nuanced understanding of TPACK-P but also how such proficiency enhances the quality of interplays. On the contrary, Asaf's interplay suggested that his KoA might inform his KoPiT to some extent, but with a more focused approach on formative assessments. However, there was limited consideration of potential disadvantages associated with technology use, and a less explicit emphasis on developing students' technology usage skills beyond specific assignments. These findings emphasize the exploration of qualitative aspects of interplays. It becomes evident that the relationship is not solely about the quantity but also about the quality of interplays, the strategic nature of connections, and how they manifest in the teachers' pedagogical approaches. This aligns with the insight from Chantaranim and Yuenyong (2017), who emphasized that higher proficiency in PCK does not necessarily mean a more integrated approach. They implied that while higher competency in PCK is important, it does not necessarily mean a more integrated approach. Thus, the present study highlights that beyond the sheer quantity of interactions, the proficiency levels of teachers significantly contribute to the qualitative aspects of TPACK-P interplays, influencing the overall learning experience. The nuanced and strategic integration of TPACK-P observed in this study not only enhances the learning experience within science education but also highlights the importance of tailored approaches to technology integration. These findings contribute to the ongoing dialogue surrounding effective teaching practices and serve as a testament to the dynamic nature of TPACK-P proficiency in shaping pedagogical strategies.

5.4. Implications of the Study

Given the findings and the key discussions, this research holds various implications

for science teachers, policy-makers and program developers, and researchers in science teaching. The following subsections succinctly outline these implications.

5.4.1. Implications for Science Teachers

The proficiency levels of in-service science teachers' TPACK-P in teaching force and energy topics hold significant implications for the evolving landscape of education. Encouraging teachers to attain the reflective application level of proficiency fosters a tailored approach, meeting the diverse needs of both teachers and students (Yeh et al., 2015a). Participation in professional development workshops is pivotal for enhancing TPACK proficiency, ultimately improving teachers' ability to integrate technology into science teaching (Mishra, 2019). Emphasizing holistic skill development, including advanced formative assessment tools and electronic assessment construction, equips teachers to navigate the intricacies of technology integration effectively (Martin, 2016). Fostering a culture of continuous professional development acknowledges the dynamic nature of technology, ensuring sustained proficiency and adaptability specifically within the context of force and energy topics. Teachers are encouraged not to overlook professional development opportunities, seizing them as occasions for improvement based on the unique demands of teaching force and energy topics. These implications collectively empower science teachers to enhance their technological proficiency in the specialized domain, creating dynamic, technology-enhanced educational experiences.

Science teachers play a pivotal role in the integration of technology into education, and several implications emerge from the findings of this study. Firstly, there is a need for continuous professional development opportunities that specifically address the integration of technology in both assessment practices and content delivery. Emphasis should be placed on enhancing teachers' proficiency in strategically using ICT tools for both formative and summative assessments. Additionally, diversifying assessment strategies, including the incorporation of educational games and interactive elements, is encouraged to cater to different learning styles and enhance student engagement. Creating collaborative learning environments through online platforms is another avenue for science teachers (Liu & Shi, 2018), fostering digital skills in students and preparing them for active participation in an interconnected world. Lastly, engaging in

reflective practice is crucial for teachers to critically assess the quality and effectiveness of their technology integration efforts, enabling them to adapt their TPACK based on their experiences (Burger, 2019; Kushner Benson et al., 2015).

In the light of the findings, integrating force and energy topics presents both challenges and opportunities for science teachers aiming to enhance their TPACK-P proficiency. The unique nature of these physics concepts, known for their abstract and challenging characteristics, demands a nuanced approach to technology integration. Professional development initiatives and workshops should be tailored to address the specific TPACK needs identified in this study, ensuring that science teachers are well-equipped to navigate the challenges of teaching force and energy topics effectively. Emphasizing interactive and engaging ICT tools for formative and summative assessments, particularly designed for force and energy topics, can significantly contribute to enhancing student comprehension and engagement. Additionally, fostering collaborative online learning environments specific to force and energy can play a crucial role in developing digital skills in students. The reflective application of TPACK within the context of force and energy ensures that technology is seamlessly integrated, creating a dynamic and effective learning environment for students.

5.4.2. Implications for Policy-makers and Program Developers

The proficiency levels of in-service science teachers' TPACK-P in teaching force and energy topics pose critical implications for policy-makers and program developers tasked with shaping science teacher education programs. This study illuminates nuanced challenges and opportunities specific to force and energy topics, emphasizing the necessity for interventions tailored to these contexts. Allocating resources for targeted professional development initiatives, such as workshops and collaborative platforms, can specifically address the identified proficiency levels and challenges in integrating technology (Mishra, 2019; O'Hara et al., 2013). By aligning ongoing professional development efforts with the evolving technology landscape in this context, policy-makers and program developers can effectively support teachers in planning and designing technology-enhanced educational experiences for science topics. Emphasizing transformative practices is crucial to advancing the quality of science education in the specific context of force and energy.

Policy-makers and program developers also play a crucial role in shaping the educational landscape. To support science teachers in effective technology integration, targeted professional development initiatives should be designed and implemented. These initiatives should address the specific needs identified in this study to enhance the overall effectiveness of technology integration in science education (Tsai, 2015). Additionally, policymakers should consider the development of flexible assessment policies that accommodate the use of technology in various forms. This flexibility allows teachers to adopt innovative assessment strategies aligned with the evolving landscape of science education. Recognizing the potential of technology-integrated assessments in promoting positive learning experiences can inform policies that encourage such practices. Furthermore, encouraging technology integration through recognition and rewards can motivate teachers to invest in enhancing their TPACK.

To enhance the proficiency levels and strengthen the interplays among TPACK-P components identified in teaching force and energy topics, policy-makers and program developers should design tailored interventions as part of science teacher education programs. These interventions could include specialized training workshops, collaborative platforms, and resources focusing on the demands of teaching force and energy concepts with ICT tools. The allocation of resources for targeted professional development initiatives, including workshops and collaborative platforms, becomes imperative. These interventions should focus on enhancing teachers' TPACK-P proficiency levels, particularly in relation to force and energy concepts. By recognizing the specific demands of force and energy topics, policy-makers can ensure that science teacher education programs provide the necessary support and training for effective technology integration in these areas.

5.4.3. Implications for Researchers in Science Teaching

The TPACK-P proficiency levels of in-service science teachers provide an intriguing avenue for researchers in science teaching to further explore. The identified categories, ranging from a lack of use to reflective application, present a nuanced framework tailored to the unique challenges and opportunities. The insights derived from this nuanced landscape of TPACK-P proficiency, as revealed by the study's results, contribute to a more detailed and intricate understanding of how teachers incorporate

technology into their pedagogical practices.

Contrary to conventional assumptions regarding the uniformity of TPACK-P proficiency across teachers, claiming a connection between higher proficiency levels among teachers and more robust interplays among TPACK components (Celik et al., 2014; Wardoyo et al., 2021), the findings challenge this notion. This challenges with existed expectations and lays the foundation for the development of targeted professional development programs. Researchers can significantly contribute to the ongoing discourse by utilizing these findings to inform future investigations, interventions, and advancements in the realm of technology integration within science education.

Moreover, considering the scarcity of research conducted in assessing TPACK specifically in teaching force and motion topics, researchers in science education can contribute significantly to the advancement of the field. Exploring the dynamics between teachers' proficiency levels in TPACK and the qualitative aspects of interplays among its components, particularly within the context of force and motion concepts, can refine existing frameworks and inform targeted interventions (Başer et al., 2016; Yeh et al., 2015a). Longitudinal studies tracking the evolution of teachers' TPACK over time can provide valuable insights into the factors influencing its development. Investigating the contextual factors influencing TPACK development across diverse educational settings can guide the customization of interventions based on specific needs (Harris & Hofer, 2009; Porras-Hernandez & Salinas-Amescua, 2013). Additionally, further exploration of the qualitative aspects of interplays among TPACK components can shed light on the nuanced relationships that contribute to effective teaching practices. Research on how teachers strategically integrate technology to enhance the quality of interactions provides a more comprehensive understanding of the impact of TPACK on the learning experience.

5.5. Recommendations of the Study

In light of the findings and discussions presented in this study, following recommendations were advised to offer practical guidance to science teachers, contribute to informed policy decisions and program development, and guide future research initiatives:

- Science teachers are encouraged to prioritize workshops that specifically address challenges in integrating technology, with a focus on content delivery and the strategic use of ICT tools in assessments.
- Teachers are advised to actively diversify assessment strategies by incorporating educational games, interactive elements, and advanced digital tools into both formative and summative assessments.
- Science teachers are encouraged to actively create collaborative learning environments through online platforms, fostering digital skills in students, and promoting active participation in a technology-rich educational setting.
- Policy-makers should consider the development of flexible assessment policies that accommodate various forms of technology integration, allowing teachers to adopt innovative assessment strategies in both formative and more importantly in summative assessments.
- It is suggested that policy-makers develop evidence-based policies regarding the impact of TPACK-P on student outcomes, ensuring strategies for integrating technology into science education in force and energy topics are informed by research findings.
- Researchers are encouraged to conduct further qualitative analyses of TPACK proficiency, unraveling the intricate connections between proficiency levels and the qualitative aspects of interplays.
- Researchers should explore the direct impact of teachers' TPACK proficiency on student learning outcomes and engagement in technology-integrated science classrooms.
- Investigating contextual factors influencing TPACK-P development across diverse educational settings is recommended, guiding the customization of interventions based on the specific needs of science teachers.
- Teachers are encouraged to actively revisit and redesign their lesson plans, particularly those related to force and energy topics, incorporating the insights

gained from professional development initiatives focused on TPACK proficiency. The integration of technology into updated lesson plans should be strategic, emphasizing effective content delivery and the purposeful use of ICT tools in teaching force and energy concepts.

- Policy-makers are encouraged to reassess the necessity for teachers to formulate daily lesson plans, reinstating a practice that facilitates a more adaptable and responsive approach to incorporating technology into the curriculum, with a particular focus on force and energy topics.
- To enhance the limited interplays of TPACK-P components identified in force and energy topics, tailored professional development programs should emphasize integrated application strategies, fostering cohesive connections between TPACK-P components. Policy-makers are urged to allocate resources for interventions that specifically target and enhance the interplays among TPACK-P components in the context of force and energy topics.

REFERENCES

- Adams, W. K. (2010). Student engagement and learning with PhET interactive simulations. *Nuovo Cimento Della Societa Italiana Di Fisica C*, 33(3), 21-32. <https://doi.org/10.1393/ncc/i2010-10623-0>.
- Agommuoh, P. C., Iroha, C. N., & Sunday, R. N. (2021). *Assessment of Senior Secondary School Teachers' Training and Usage of Information Communication Technology (ICT) in Science Teaching* [The 3rd International Conference on New Approaches in Education].
- Ahmad, A. S., & Hamad, K. Y. (2020). Technology Integration in Teaching: A Study that Examines How Technology Integration Affects Student Achievement. *Journal of Education and Culture Studies*, 4(3), 44-52. <https://doi.org/10.22158/jecs.v4n3p44>
- Ahn, J. (2020). *Understanding teachers' beliefs and practices in technology use in a Korean language classroom through exploratory practice* [Phd Dissertation]. University of Wisconsin-Madison.
- Akay, C. (2013). Teknoloji temelli öğretim tasarımları hazırlama ve uygulama ilkeleri [Principles of preparing and implementing technology-based instructional designs]. In T. Yanpar Yelken, H. Sancar Tokmak, S. Özgelen, & L. İncikapı (Eds.), *Fen ve matematik eğitiminde teknolojik pedagojik alan bilgisi temelli öğretim tasarımları* (pp. 129–148). Anı Yayıncılık.
- Akın, F. N., & Uzuntiryaki-Kondakci, E. (2018). The nature of the interplay among components of pedagogical content knowledge in reaction rate and chemical equilibrium topics of novice and experienced chemistry teachers. *Chemistry Education Research and Practice*, 19(1), 80-105.
- Aktaş, İ., & Özmen, H. (2022). Assessing the performance of Turkish science pre-service teachers in a TPACK-practical course. *Education and Information Technologies*, 27(3), 3495-3528.
- Akyuz, D. (2018). Measuring technological pedagogical content knowledge (TPACK) through performance assessment. *Computers & Education*, 125, 212-225.
- Albayrak Sarı, A., Bilici, S. C., Baran, E., & Özbay, U. (2016). Farklı Branşlardaki

Öğretmenlerin Teknolojik Pedagojik Alan Bilgisi (TPAB) Yeterlikleri ile Bilgi ve İletişim Teknolojilerine Yönelik Tutumları Arasındaki İlişkinin İncelenmesi. *Eğitim Teknolojisi Kuram ve Uygulama*, 6(1). <https://doi.org/10.17943/etku.11643>

Albion, P., & Tondeur, J. (2018). Information and communication technology and education: meaningful change through teacher agency. In J. Voogt, G. Knezek, R. Christensen, & K. W. Lai (Eds.), *Second handbook of information technology in primary and secondary education* (2nd ed., pp. 1–16). Springer.

Ali, M. (2020). Student Engagement and ICT: A Meta-Analysis. *Mukt Shabd Journal*, 9(5), 2326-2332.

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.

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.

Angeli, C., Valanides, N., & Christodoulou, A. (2016). Theoretical considerations of technological pedagogical content knowledge. In M. C. Herring, M. J. Koehler, & P. Mishra (Eds.), *Handbook of technological pedagogical content knowledge (TPACK) for educators* (2nd ed., pp. 11-32). Routledge.

Archambault, L. M., & Barnett, J. H. (2010). Revisiting technological pedagogical content knowledge: Exploring the TPACK framework. *Computers & Education*, 55(4), 1656-1662.

Arora, R., & Friedman, T. L. (2009). The K-12 online evolution. *MultiMedia & Internet@ Schools*, 16(6), 16-19.

Avci, B. (2017). *The Effect of Teacher Candidates on Lego Mindstorm Robotics Projects on Technological Pedagogical Content Knowledge, Problem Solving and Scientific Creativity*. [Master's thesis] Marmara University.

Ay, Y., Karadağ, E., & Acat, M. B. (2015). The technological pedagogical content knowledge-practical (TPACK-Practical) model: Examination of its validity in the Turkish culture via structural equation modeling. *Computers & Education*, 88, 97-108.

- Aydin, S., & Boz, Y. (2013). The nature of integration among PCK components: A case study of two experienced chemistry teachers. *Chemistry Education Research and Practice*, 14(4), 615-624.
- Aydin, S., Demirdogen, B., Akin, F. N., Uzuntiryaki-Kondakci, E., & Tarkin, A. (2015). The nature and development of interaction among components of pedagogical content knowledge in practicum. *Teaching and teacher education*, 46, 37-50.
- Aydin-Gunbatar, S., Kaplan, N., & Akin, F. N. (2023). The Integrations of Elementary Science Teachers' Technological Pedagogical Content Knowledge Components during COVID-19: Teaching Electric Circuits and Circuit Diagrams. *Research in Science Education*. <https://doi.org/10.1007/s11165-023-10147-0>
- Baran, E., & Canbazoğlu-Bilici, S. (2015). A review of the research on technological pedagogical content knowledge: The case of Turkey. *Hacettepe University Journal of Education*, 30(1), 15–32.
- Başer, D., Kopcha, T.J., & Ozden, M. (2016). Developing a technological pedagogical content knowledge (TPACK) assessment for preservice teachers learning to teach English as a foreign language. *Computer Assisted Language Learning*, 29, 749-764.
- Bayyigit Teker, S. (2019). Öğretmenlerin teknolojik pedagojik alan bilgisi (TPAB) yeterlilikleri ile eğitim bilişim ağı (EBA) kullanımına yönelik tutumları arasındaki ilişki [MS Thesis]. Balıkesir University.
- Bennett, S., Dawson, P., Bearman, M., Molloy, E., & Boud, D. (2017). How technology shapes assessment design: Findings from a study of university teachers. *British Journal of Educational Technology*, 48(2), 672-682.
- Bibi, S., & Khan, S. (2016). TPACK in action: A study of a teacher educator's thoughts when planning to use ICT. *Australasian Journal of Educational Technology*, 33, 70-87.
- Bowers, J. S., & Stephens, B. (2011). Using technology to explore mathematical relationships: A framework for orienting mathematics courses for prospective teachers. *Journal of Mathematics Teacher Education*, 14, 285-304.
- Buchholz, M., Saeli, M., & Schulte, C. (2013). PCK and reflection in computer science teacher education. *WiPSE'13: Proceedings of the 8th Workshop in Primary and Secondary Computing Education*, 8–

- Burger, J. (2019). *Elementary grade educators' evaluation of technology integration through reflection: A basic qualitative study* [Doctoral dissertation]. Capella University.
- Cakir, R., & Yildirim, S. (2013). ICT teachers' professional growth viewed in terms of perceptions about teaching and competencies. *Journal of Information Technology Education. Innovations in Practice*, 12, 221.
- 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.
- Carlsen, W. S. (1999). Domains of teacher knowledge. In J. Gess-Newsome & N. G. Lederman (Eds.), *Examining pedagogical content knowledge: The construct and its implications for science education* (Vol. 6, pp. 133-146). Kluwer Academic Publishers.
- Carlson, E. (1994). Staff development for multimedia: coping with complexity. In A. Ward (Ed.), *Multimedia and learning: a school leader's guide* (pp. 53-60). National School Boards Association.
- Cavas, B., Cavas, P., Karaoglan, B., & Kislal, T. (2009). A Study on Science Teachers' Attitudes Toward Information and Communications Technologies in Education. *Online Submission*, 8(2), 1-13.
- Celik, I., Sahin, I., & Akturk, A. O. (2014). Analysis of the relations among the components of technological pedagogical and content knowledge (TPACK): A structural equation model. *Journal of educational computing research*, 51(1), 1-22.
- Çetin, A., & Ünsal, S. (2019). Merkezi sınavların öğretmenler üzerinde sosyal, psikolojik etkisi ve öğretmenlerin öğretim programı uygulamalarına yansımaları [Social, psychological effects of central examinations on teachers and their reflections on teachers' curriculum implementations]. *Hacettepe University Journal of Education*, 34(2), 304-323.
- Chai, C. S., Koh, J. H. L., & Tsai, C. C. (2013). A review of technological pedagogical content knowledge. *Journal of Educational Technology & Society*, 16(2), 31-51.

- Chantaranima, T., & Yuenyong, C. (2017). Competencies of Thai expertise teacher and PCK. *Proceedings of the 5th International Conference for Science Educators and Teachers (ISET) 2017*, 1923(1), 030065. <https://doi.org/10.1063/1.5019556>
- Chen, Y. J., & Hsu, R. L. W. (2021). Understanding the difference of teachers' TPACK before and during the COVID-19 pandemic: Evidence from two groups of teachers. *Sustainability*, 13(8827), 1-17.
- Cheremisin, P. A., Davydova, A. A., Meleshkina, E., Goltseva, O. S., & Zhilina, A. V. (2022). Digitalization as a new educational paradigm. *Política E Gestão Educacional*, e022060. <https://doi.org/10.22633/rpge.v26iesp.2.16558>
- Creswell, J. W. (2009). *Research design: Qualitative, quantitative, and mixed methods approaches* (3rd ed.). Sage Publications.
- Culp, K. M., Honey, M., & Mandinach, E. (2005). A retrospective on twenty years of education technology policy. *Journal of Educational Computing Research*, 32(3), 279-307.
- Deng, F., Lan, W., Sun, D., & Zheng, Z. (2023). Examining Pre-Service Chemistry Teachers' Technological Pedagogical Content Knowledge (TPACK) of Using Data-Logging in the Chemistry Classroom. *Sustainability*, 15(15441), 1-21.
- Diken, E. H. (2018). Fen bilgisi öğretmenleri ile 8. sınıf öğrencilerinin temel eğitimden ortaöğretime geçiş (TEOG) sınavındaki kaygılarına yönelik görüşleri (Kars İli Örneği) [The opinions of science teachers and 8th grade students regarding TEOG exam anxiety (The Case of Kars province)]. *İnsan ve Toplum Bilimleri Araştırmaları Dergisi*, 7(2), 718-741.
- Dilworth, P., Donaldson, A., George, M., Knezek, D., Searson, M., Starkweather, K., Strutchens, M., Tillotson, J., & Robinson, S. (2012). Preparing teachers for tomorrow's technologies. *TechTrends*, 56(4), 11-14. <https://doi.org/10.1007/s11528-012-0581-5>
- Dini, V., Sevia, H., Caushi, K., & Orduña Picón, R. (2020). Characterizing the formative assessment enactment of experienced science teachers. *Science Education*, 104(2), 290-325.
- Dodson, J. R. (2014). The Impact of Online Homework on Class Productivity. *Science Education International*, 25(4), 354-371.

- Doorn, D. J., Janssen, S., & O'Brien, M. (2010). Student Attitudes and Approaches to Online Homework. *International Journal for the scholarship of teaching and learning*, 4(1), 1-20.
- Efiliti, E., & Çoklar, A. N. (2013). The study of the relationship between teachers' teaching styles and TPACK education competencies. *World Journal on Educational Technology*, 5(3), 348–357.
- Efimova, E.A. (2021). What future for digital homework: Literature review. *Informatics and education*. 6, 51-59.
- Elsayed, M. M. S., & Puteh-Behak, F. (2017). Saudi undergraduate EFL students' perceptions towards learning together strategy implementation in an EFL reading comprehension course. *International E-Journal of Advances in Education*, 3(8), 289–297.
- Erduran, A., & Ince, B. (2018). Identifying Mathematics Teachers' Difficulties in Technology Integration in Terms of Technological Pedagogical Content Knowledge (TPCK). *International Journal of Research in Education and Science*, 4(2), 555-576.
- Evawati, D., & Susilowati, S., (2023). Optimization of Nutrition Science Learning through Educational Technology at PGRI Adi Buana University Surabaya. *Jurnal Iqra': Kajian Ilmu Pendidikan*, 8(1). 385-401 <https://doi.org/10.25217/ji.v8i1.2734>
- Felix, A. A. (2015). *Dominant pedagogies used in three rural Geography primary school classrooms in the West Coast district* [Doctoral dissertation] Cape Peninsula University of Technology.
- Fisser, P., Voogt, J., Van Braak, J., & Tondeur, J. (2015). Measuring and assessing TPACK (technological, pedagogical content knowledge). *The SAGE Encyclopedia of Educational Technology*. 2, 490-493.
- Gess-Newsome J (1999) Pedagogical content knowledge: An introduction and orientation. In J Gess-Newsome & NG Lederman (Eds.), *Examining pedagogical content knowledge: The construct and its implications for science education* (pp. 3-17). Kluwer Academic Publishers.
- Gess-Newsome, J., & Lederman, N. G. (1993). Preservice Biology Teachers' Knowledge Structures as a Function of Professional Teacher Education: A Year-Long Assessment. *Science Education*, 77(1), 25-45.

- Gipps, C. V. (2005). What is the role for ICT- based assessment in universities?. *Studies in Higher Education*, 30(2), 171-180.
- Glaser, B. G., & Strauss, A. L. (1967). *The discovery of grounded theory: Strategies for qualitative research*. Aldine Publishing Company.
- Graham, C. R. (2011). Theoretical considerations for understanding technological pedagogical content knowledge (TPACK). *Computers & Education*, 57(3), 1953-1960.
- Graziano, K. J., Foulger, T. S., Schmidt-Crawford, D. A., & Slykhuis, D. (2017, March). Technology integration and teacher preparation: The development of teacher educator technology competencies. In *Society for Information Technology & Teacher Education International Conference* (pp. 2336-2346). Association for the Advancement of Computing in Education (AACE).
- Greene, M., & Jones, W. (2020). Towards a critical conceptual framework for technology integration in professional development for English language teachers. *Journal of Educational Multimedia and Hypermedia*, 29(2), 113-132.
- Grossman, P. L. (1990). *The making of a teacher: Teacher knowledge and teacher education*. Teachers College Press.
- Groth, R., Spickler, D., Bergner, J., & Bardzell, M. (2009). A qualitative approach to assessing technological pedagogical content knowledge. *Contemporary Issues in Technology and Teacher Education*, 9(4), 392-411.
- Habibu, T., Abdullah-Al-Mamun, M. D., & Clement, C. (2012). Difficulties faced by teachers in using ICT in teaching-learning at technical and higher educational institutions of Uganda. *International Journal of Engineering*, 1(7), 1–10.
- Hafez, T. Y. (2022). Game-based Assessment in Educational Institutes. *Egyptian Journal of Specialized Studies*, 10(34), 5–21.
- Hamid, S.R., Hassan, S.S., & Ismail, N.A. (2012). Teaching Quality and Performance Among Experienced Teachers in Malaysia. *Australian Journal of Teacher Education*, 37(11), 85-103.
- Harish, H. G., Kumar, R. K., & Raja, B. (2013). Bringing ICT to Teach Science Education for Students with Learning Difficulties. *Journal on School Educational Technology*, 8(4), 1-5.

- Harris, J., & Hofer, M. (2009, March). Instructional planning activity types as vehicles for curriculum-based TPACK development. In *Society for information technology & teacher education international conference* (pp. 4087-4095). Association for the Advancement of Computing in Education (AACE).
- Harris, J., Grandgenett, N., & Hofer, M. (2010, March). Testing a TPACK-based technology integration assessment rubric. In *Society for Information Technology & Teacher Education International Conference* (pp. 3833-3840). Association for the Advancement of Computing in Education (AACE).
- Hashim, H. (2018). Application of technology in the digital era education. *International Journal of Research in Chemistry and Environment*. 1(2), 1-5.
- Helppolainen, S., & Aksela, M. (2015). Science teachers' ICT use from a viewpoint of technological pedagogical content knowledge (TPCK). *LUMAT*, 3(6), 783–799.
- Herbert, N. (2017). Impact of Student Engagement on First Year ICT Performance. *2017 International Conference on Computational Science and Computational Intelligence (CSCI)*, 1085–1090. <https://doi.org/10.1109/csci.2017.189>
- Hofer, M., & Harris, J. (2010, March). Differentiating TPACK development: Using learning activity types with inservice and preservice teachers. In *Society for Information Technology & Teacher Education International Conference* (pp. 3857-3864). Association for the Advancement of Computing in Education (AACE).
- Ihde, D., & Kemp, P. (2004). Philosophy of Technology. In *Philosophical Problems Today* (Vol. 3, pp. 91–108). Springer. https://doi.org/10.1007/1-4020-3027-4_3
- International Society for Technology in Education. (2008). National Education Technology Standards (NETS-T) and performance indicators for teachers. Retrieved September 22, 2018, from https://www.iste.org/docs/pdfs/20-14_ISTE_Standards-T_PDF.pdf
- Ismajli, H., Bytyqi-Damoni, A., Shatri, K., & Özoğul, G. (2020). Coaching teachers to integrate technology: The effects of technology integration on student performance and critical thinking. *İlköğretim Online*, 19(3), 1306–1320.
- Jaakkola, T., Nurmi, S., & Veermans, K. (2011). A comparison of students' conceptual understanding of electric circuits in simulation only and simulation-

- laboratory contexts. *Journal of research in science teaching*, 48(1), 71-93.
- 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.
- Jen, T. H., Yeh, Y. F., Hsu, Y. S., Wu, H. K., & Chen, K. M. (2016). Science teachers' TPACK-Practical: Standard-setting using an evidence-based approach. *Computers & Education*, 95, 45-62.
- Jhurree, V. (2005). Technology integration in education in developing countries: Guidelines to policy makers. *International Education Journal*, 6(4), 467-483.
- Jimoyiannis, A. (2010). Designing and implementing an integrated technological pedagogical science knowledge framework for science teachers professional development. *Computers & Education*, 55(3), 1259-1269.
- Jones, A., & Moreland, J. (2004). Enhancing practicing primary school teachers' pedagogical content knowledge in technology. *International journal of technology and design education*, 14, 121-140.
- Juliantari, N. K., Sudarsana, I. K., Sutriyanti, N. K., Astawa, I. N. T., Putri, I. D. a. H., & Saddhono, K. (2018). Educational games based in information technology as innovation evaluation activity in learning. *Journal of Physics: Conference Series*, 1114(012041), 1-4. <https://doi.org/10.1088/17426596/1114/1/012041>
- Kabakçı-Yurdakul, I., Odabaşı, H. F., Kılıçer, K., Çoklar, A. N., Birinci, G., & Kurt, A. A. (2014). Constructing technopedagogical education based on teacher competencies in terms of national standards. *Elementary Education Online*, 13(4), 1185-1202.
- Kafyulilo, A., Fisser, P., Pieters, J., & Voogt, J. (2015). ICT Use in Science and Mathematics Teacher Education in Tanzania: Developing Technological Pedagogical Content Knowledge. *Australasian Journal of Educational Technology*, 31(4), 381-399.
- Kakhkhorov, S. K., & Rasulova, Z. D. (2020). Methodology of improving the professional activity of the future teacher of technology on the basis of modern educational technologies. *Universal Journal of Educational Research*, 8(12), 7006-7014.
- 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(1), 25-43.

Kearney, M., Pressick-Kilborn, K., & Maher, D. (2012, March). Driving pre-service science teachers' TPACK development through their generative use of digital video. In *Society for Information Technology & Teacher Education International Conference* (pp. 1381-1388). Association for the Advancement of Computing in Education (AACE).

Khine, M. S., Ali, N., & Afari, E. (2017). Exploring relationships among TPACK constructs and ICT achievement among trainee teachers. *Education and information technologies*, 22, 1605-1621.

Kiray, S.A. (2016). Development of a TPACK self-efficacy scale for preservice science teachers. *International Journal of Research in Education and Science (IJRES)*, 2(2), 527-541.

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.

Koehler, M. J., Mishra, P., & Yahya, K. (2007). Tracing the development of teacher knowledge in a design seminar: Integrating content, pedagogy and technology. *Computers & Education*, 49(3), 740-762.

Koehler, M. J., Shin, T. S., & Mishra, P. (2012). How do we measure TPACK? Let me count the ways. In *Educational technology, teacher knowledge, and classroom impact: A research handbook on frameworks and approaches* (pp. 16-31). IGI Global.

Koehler, M., & Mishra, P. (2009). What is technological pedagogical content knowledge (TPACK)? *Contemporary issues in technology and teacher education*, 9(1), 60-70.

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.

Koh, J. H. L., Chai, C. S., & Lee, M.-H. (2015). Technological pedagogical content knowledge (TPACK) for pedagogical improvement: Editorial for special issue on TPACK. *The Asia-Pacific Education Researcher*, 24(3), 459-462.

- Koh, J. H. L., Chai, C. S., & Tsai, C.-C. (2013). Examining practicing teachers' perceptions of technological pedagogical content knowledge (TPACK) pathways: a structural equation modeling approach. *Instructional Science*, 41(4), 793–809.
- Koh, J. H., & Divaharan, H. (2011). Developing pre-service teachers' technology integration expertise through the TPACK-developing instructional model. *Journal of Educational Computing Research*, 44(1), 35-58.
- Koh, J.H., Chai, C.S., & Tay, L.Y. (2014). TPACK-in-Action: Unpacking the contextual influences of teachers' construction of technological pedagogical content knowledge (TPACK). *Computer Education*, 78, 20-29.
- Koni, I., & Krull, E. (2018). Differences in novice and experienced teachers' perceptions of planning activities in terms of primary instructional tasks. *Teacher Development*, 22(4), 464–480. <https://doi.org/10.1080/13664530.2018.1442876>
- Kopcha, T. J., Neumann, K. L., Ottenbreit-Leftwich, A., & Pitman, E. (2020). Process over product: The next evolution of our quest for technology integration. *Educational Technology Research and Development*, 68, 729-749.
- 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.
- Kristiawan, D., Carter, C., & Picard, M. (2022). Impact of Call Professional Development for EFL Materials on Teacher Agency and Technological Pedagogical Content Knowledge (TPACK) in Indonesian Islamic Schools. *Teaching English with Technology*, 22, 20-42.
- Kushner Benson, S. N. K., Ward ve C. L. Liang, X. (2015). The essential role of pedagogical knowledge in technology integration for transformative teaching and learning. In C. Angeli & A. Valanides (Eds.), *Technological Pedagogical Content Knowledge: Exploring, Developing, and Assessing TPCK* (pp. 3-18). Springer.
- Lawless, K. A., & Pellegrino, J. W. (2007). Professional development in integrating technology into teaching and learning: Knowns, unknowns, and ways to pursue better questions and answers. *Review of educational research*, 77(4), 575-614.

- LeCompte, M. D., Preissle, J., & Tesch, R. (1993). *Ethnography and qualitative design in educational research*. Academic Press.
- 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(3), 325-336.
- Lin, T., & Hsu, Y. S. (2015). The Current Status of Science Teachers' TPACK in Taiwan from Interview Data. In Y. S. Hsu (Ed.), *Development of Science Teachers' TPACK* (pp. 33-50). https://doi.org/10.1007/978-981-287-441-2_3
- Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic inquiry*. Thousand Oaks.
- Liu, R., & Shi, C. (2018). Exploring different types of interaction on collaborative learning in online platforms. *International Journal of Innovation and Learning*, 23(4), 386-399.
- Loor, J.M., Mera, J.L., Palma, J., Escobar, M.R., & Aguilar, E.E. (2020). Application of Formative Assessment Instruments to Improve Teaching-learning Process. *International Journal of Engineering and Computer Science*, 3, 7-16.
- Lopez-Lozano, L., Solís, E., & Azcárate, P. (2018). Evolution of ideas about assessment in science: Incidence of a formative process. *Research in Science Education*, 48, 915-937.
- Luke, C. L., & Britten, J. S. (2007). The expanding role of technology in foreign language teacher education programs. *Calico Journal*, 24(2), 253-267.
- Lyublinskaya, I., & Tournaki, N. (2014). A study of special education teachers' TPACK development in mathematics and science through assessment of lesson plans. *Journal of Technology and Teacher Education*, 22(4), 449-470.
- Magnusson, S., Krajcik, J., & Borko, H. (1999). Nature, sources and development of pedagogical content knowledge for science teaching. In J. Gess-Newsome & N.G. Lederman (Eds.), *Examining pedagogical content knowledge: The construct and its implications for science education* (pp. 95–132). Kluwer Academic Publishers.
- Mandacı Şahin, S., Aydoğan Yenmez, A., Özpınar, İ., & Köğce, D. (2013). Öğretmen adaylarının teknolojik pedagojik alan bilgisi modeline uygun bir hizmet öncesi eğitim programının bileşenlerine ilişkin görüşleri [Teacher

Candidates' Views on the Components of a Pre-Service Training Program Based on the Technological Pedagogical Content Knowledge Model]. *Hacettepe University Journal of Education, Special issue* (1), 271-286.

Maor, D. (2013). Does the use of the TPACK model enhance digital pedagogies: We don't understand the present so how can we imagine the future?. In *ASCILITE-Australian Society for Computers in Learning in Tertiary Education Annual Conference* (pp. 531-540). Australasian Society for Computers in Learning in Tertiary Education.

Martin, M. (2016). *Blending instruction with technology: A blueprint for teachers to create unique, engaging, and effective learning experiences*. Rowman & Littlefield.

Masterman, E., & Manton, M. (2011). Teachers' perspectives on digital tools for pedagogic planning and design. *Technology, Pedagogy and Education*, 20(2), 227-246.

Mavhunga, E., & Rollnick, M. (2013). Improving PCK of Chemical Equilibrium in Pre-service Teachers. *African Journal of Research in Mathematics, Science and Technology Education*, 17, 113-125.

McKnight, K., O'Malley, K., Ruzic, R., Horsley, M. K., Franey, J. J., & Bassett, K. (2016). Teaching in a digital age: How educators use technology to improve student learning. *Journal of research on technology in education*, 48(3), 194-211.

Meagher, M., Ozgun-Koca, A., & Edwards, M. T. (2011). Pre-service teachers' experiences with advanced digital technologies: The interplay between technology in a pre-service classroom and in field placements. *Contemporary Issues in Technology and Teacher Education*, 11(3), 243-270.

Megalakaki, O., & Thibaut, J. P. (2016). Development and differentiation of force and energy concepts for animate and inanimate objects in children and adolescents. *Research in Science Education*, 46, 457-480.

Merriam, S. B., & Tisdell, E. J. (2016). *Qualitative research: A guide to design and implementation*. John Wiley & Sons.

Mishra, P. & Koehler, M. J. (2006). Technological Pedagogical Content Knowledge: A Framework for Teacher Knowledge. *Teachers College Record*, 108(6), 1017-1054.

- Mishra, P. (2019). Considering contextual knowledge: The TPACK diagram gets an upgrade. *Journal of Digital Learning in Teacher Education*, 35(2), 76-78.
- Mourlam, D., Chesnut, S., Strouse, G., DeCino, D., Los, R., & Newland, L. (2021, March). Did they forget? Understanding teacher TPACK during the COVID-19 pandemic. In *Society for Information Technology & Teacher Education International Conference* (pp. 1616-1622). 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 *Handbook of technological pedagogical content knowledge (TPACK) for educators* (pp. 169-190). Routledge.
- Mouza, C., & Karchmer-Klein, R. (2013). Promoting and assessing pre-service teachers' technological pedagogical content knowledge (TPACK) in the context of case development. *Journal of Educational Computing Research*, 48(2), 127-152.
- Murphy, C., & Smith, G. (2012). The impact of a curriculum course on pre-service primary teachers' science content knowledge and attitudes towards teaching science. *Irish Educational Studies*, 31, 77-95.
- National Commission on Teaching & America's Future (US). (2003). *No dream denied: A pledge to America's children*. National Commission on Teaching and America's Future.
- National Research Council. (2012). *A framework for K-12 science education: practices, crosscutting concepts, and core ideas*. The National Academies Press. <https://doi.org/10.17226/13165>.
- Niess, M. L. (2011). Investigating TPACK: Knowledge growth in teaching with technology. *Journal of Educational Computing Research*, 44(3), 299-317.
- O'Hara, S., Pritchard, R., Huang, C., & Pella, S. (2013). Learning to integrate new technologies into teaching and learning through a design-based model of professional development. *Journal of Technology and Teacher Education*, 21(2), 203-223.
- Ocak, C., & Baran, E. (2019). Observing the indicators of technological pedagogical content knowledge in science classrooms: Video-based research. *Journal of Research on Technology in Education*, 51(1), 43-62.

- Ogebo, A.A. (2023). Assessing the proficiency level in digital competences of secondary school science teachers. *International Journal of Education and Development using Information and Communication Technology (IJEDICT)*, 19(2), 40-57.
- Özden, M. (2007). Problems with Science and Technology Education in Turkey. *Eurasia journal of mathematics, science and technology education*, 3, 157-161.
- Özgen, K., & Narli, S. (2020). Intelligent data analysis of interactions and relationships among technological pedagogical content knowledge constructs via rough set analysis. *Contemporary Educational Technology*, 11(1), 77-98.
- Paje, Y. M., Rogayan Jr, D. V., & Dantic, M. J. P. (2021). Teachers' utilization of computer-based technology in science instruction. *International Journal of Technology in Education and Science*, 5(3), 427-446.
- Pamuk, S., Ergun, M., Cakir, R., Yilmaz, H. B., & Ayas, C. (2015). Exploring relationships among TPACK components and development of the TPACK instrument. *Education and Information Technologies*, 20, 241-263.
- Park, S., & Chen, Y. C. (2012). Mapping out the integration of the components of pedagogical content knowledge (PCK): Examples from high school biology classrooms. *Journal of research in science teaching*, 49(7), 922-941.
- Patton, M. Q. (2015). *Qualitative research and evaluation methods* (4th ed.). Sage Publications.
- Pellegrino, J.W., & Quellmalz, E.S. (2010). Perspectives on the Integration of Technology and Assessment. *Journal of Research on Technology in Education*, 43, 119- 134.
- Pieters, A. E. (2018). *Assessing the Technological Pedagogical Content Knowledge Proficiency of Preservice Science Teachers* [PhD Dissertation]. University of Johannesburg.
- Porras-Hernández, L. H., & Salinas-Amescua, B. (2013). Strengthening TPACK: A broader notion of context and the use of teacher's narratives to reveal knowledge construction. *Journal of Educational Computing Research*, 48(2), 223-244.
- Priestley, M., Biesta, G., & Robinson, S. (2015). *Teacher Agency: What Is It and Why*

Does It Matter? (1st ed.). Routledge.

- Pringle, R. M., Dawson, K., & Ritzhaupt, A. D. (2015). Integrating science and technology: Using technological pedagogical content knowledge as a framework to study the practices of science teachers. *Journal of Science Education and Technology*, 24(5), 648-662.
- Purcell, K., Heaps, A., Buchanan, J., & Friedrich, L. (2013). *How teachers are using technology at home and in their classrooms*. Pew Research Center's Internet & American Life Project. Retrieved September 3, 2023, from <https://fiscalresearchcenter.issuelab.org/resources/14773/14773.pdf>
- Ramnarain, U., Pieters, A., & Wu, H. K. (2021). Assessing the technological pedagogical content knowledge of pre-service science teachers at a South African university. *International Journal of Information and Communication Technology Education (IJICTE)*, 17(3), 123-136.
- Redmond, P., Lock, J., & Danaher, P. (Eds.). (2015). *Educational innovations and contemporary technologies: enhancing teaching and learning*. Springer.
- Reiser, R. A. (1994). Examining the Planning Practices of Teachers: Reflections on Three Years of Research. *Educational Technology*, 34(3), 11-16.
- Rollnick, M. (2017). Learning about semi conductors for teaching—The role played by content knowledge in pedagogical content knowledge (PCK) development. *Research in Science Education*, 47, 833-868.
- Roy, A. (2019). Technology in teaching and learning. *International Journal of Innovation Education and Research*, 7(4), 414-422.
- Russell, M., Bebell, D., O'Dwyer, L., & O'Connor, K. (2003). Examining teacher technology use: Implications for preservice and inservice teacher preparation. *Journal of teacher Education*, 54(4), 297-310.
- Salehi, H., & Salehi, Z. (2012). Do high-stakes tests facilitate or hinder the use of ICT in the classroom? *3rd International Conference on e-Education, e-Business, e-Management and e-Learning IPEDR*, 27, 210–214.
- Saubern, R., Urbach, D., Koehler, M., & Phillips, M. (2020). Describing increasing proficiency in teachers' knowledge of the effective use of digital technology. *Computers & Education*, 147(103784). 1-13.

- 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), 1-12.
- 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.
- Şen, M., Demirdöğen, B., & Öztekin, C. (2022). Interactions among topic-specific pedagogical content knowledge components for science teachers: The impact of content knowledge. *Journal of Science Teacher Education*, 33(8), 860-887.
- Şentürk, M. L. (2017) *Physics teachers' animation & simulation-TPACK levels on force and motion: in-class holistic multiple case study*. [Doctoral Dissertation] Gazi University.
- Setiawan, H., Phillipson, S., Sudarmin, & Isnaeni, W. (2019). Current trends in TPACK research in science education: a systematic review of literature from 2011 to 2017. *Journal of Physics: Conference Series*, 1317(1). <https://doi.org/10.1088/1742-6596/1317/1/012213>
- Sherin, M. G., & Drake, C. (2009). Curriculum strategy framework: investigating patterns in teachers' use of a reform- based elementary mathematics curriculum. *Journal of Curriculum Studies*, 41(4), 467-500.
- Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, 15(2), 4-14.
- Shulman, L. S. (1987). Knowledge and Teaching: Foundations of the new reform. *Harvard Educational Review*, 57(1), 1-22.
- Sullivan, S., Gnesdilow, D., Puntambekar, S., & Kim, J. S. (2017). Middle school students' learning of mechanics concepts through engagement in different sequences of physical and virtual experiments. *International Journal of Science Education*, 39(12), 1573-1600.
- Szymkowiak, A., Melović, B., Dabić, M., Jeganathan, K., & Kundi, G. S. (2021). Information technology and Gen Z: The role of teachers, the internet, and technology in the education of young people. *Technology in Society*, 65(101565), 1-10. <https://doi.org/10.1016/j.techsoc.2021.101565>

- Tanrisevdi, M. (2021) *Investigating Science Teachers' Technological Pedagogical Content Knowledge (TPACK) Competencies: A Mixed Method Study* [PhD Dissertation]. Middle East Technical University.
- Taş, Y., & Balgalmış, E. (2016). Turkish Mathematics and Science Teachers' Technology Use in Their Classroom Instruction: Findings from TIMSS 2011. *Journal of Education in Science, Environment and Health*, 2(2), 166-175.
- Tasar, M.F., & Timur, B. (2010). *Developing technological pedagogical content knowledge in pre-service science teachers through microteaching via inquiry based interactive physics computer animations*. GIREP-ICPE-MPTL Conference, 22-29 August, 2010, Reims, France.
- The Council of The European Union. (2018). *Council Recommendation of 22 May 2018 on key competences for lifelong learning* (2018/C 189/01). Official Journal of the European Union.
- Timur, B. (2011) The development of pre-service science teachers' technological pedagogical content knowledge in force and movement subjects [Doctoral Dissertation]. Gazi University.
- Tondeur, J., Howard, S., Van Zanten, M., Gorissen, P., Van der Neut, I., Uerz, D., & Kral, M. (2023). The HeDiCom framework: Higher Education teachers' digital competencies for the future. *Educational technology research and development*, 71(1), 33-53.
- Tondeur, J., Kershaw, L. H., Vanderlinde, R. R., & Van Braak, J. (2013). Getting inside the black box of technology integration in education: Teachers' stimulated recall of classroom observations. *Australasian Journal of Educational Technology*, 29(3), 434-449.
- Topper, A., & Lancaster, S. (2013). Common challenges and experiences of school districts that are implementing one-to-one computing initiatives. *Computers in the Schools*, 30(4), 346-358.
- Tsai, H. C. (2015). A senior teacher's implementation of technology integration. *International Education Studies*, 8(6), 151-161.
- Tuithof, J. I. G. M. (2017). *The characteristics of Dutch experienced history teachers' PCK in the context of a curriculum innovation* [Doctoral dissertation]. Utrecht University.

- Tuncel, M., & Fidan, M. (2018). Subjects perceived as difficult in secondary science course and recommendations. In H. I. Kaya, & O. Demir (Eds.). *Curriculum studies in secondary education* (pp. 49-55). Pegem Academy.
- Turan, Z. (2023). Evaluating whether flipped classrooms improve student learning in science education: A systematic review and meta-analysis. *Scandinavian Journal of Educational Research*, 67(1), 1-19.
- Turkish Ministry of National Education (2018). National Education Statistics Formal Education 2017-2018. Retrieved March 10, 2021 from http://sgb.meb.gov.tr/meb_iys_dosyalar/2018_09/06123056_meb_istatistikleri_orgun_egitim_2017_2018.pdf
- Turkish Ministry of National Education. (2015). *2015-2019 Strategic Plans of the Turkish Ministry of National Education*. Retrieved July 14, 2023, from https://sgb.meb.gov.tr/meb_iys_dosyalar/2015_09/10052958_10.09.2015sp17.15imzasz.pdf
- Turkish Ministry of National Education. (2019). *2019-2023 Strategic Plans of the Turkish Ministry of National Education*. Retrieved July 14, 2023, from https://www.meb.gov.tr/stratejik_plan/
- Ucar, M.B., & Sahin, E. (2018). *A Review on Assessment of Technological Pedagogical Content Knowledge for Pre-Service Science Teachers*. In *27th International Congress on Educational Sciences (ICES/UEBK-2018)* (pp. 2099-2108). Pegem Academy.
- Vahasantanen, K. (2015). Professional agency in the stream of change: Understanding educational change and teachers' professional identities. *Teaching and teacher education*, 47, 1-12.
- Valanides, N., & Angeli, C. (2006). Preparing preservice elementary teachers to teach science through computer models. *Contemporary Issues in Technology and Teacher Education*, 6(1), 87-98.
- Valtonen, T., Leppänen, U., Hyypiä, M., Sointu, E., Smits, A., & Tondeur, J. (2020). Fresh perspectives on TPACK: pre-service teachers' own appraisal of their challenging and confident TPACK areas. *Education and Information Technologies*, 25(4), 2823-2842.
- Van Driel, J. H., & Berry, A. (2012). Teacher professional development focusing on pedagogical content knowledge. *Educational researcher*, 41(1), 26-28.

- Van Driel, J. H., Beijaard, D., & Verloop, N. (2001). Professional development and reform in science education: The role of teachers' practical knowledge. *Journal of Research in Science Teaching*, 38(2), 137-158.
- Van Driel, J. H., De Vos, W., Verloop, N., & Dekkers, H. (1998). Developing secondary students' conceptions of chemical reactions: The introduction of chemical equilibrium. *International Journal of Science Education*, 20(4), 379-392.
- Van Driel, J., & Berry, A. (2010). Pedagogical content knowledge. In *Elsevier eBooks* (pp. 656–661). <https://doi.org/10.1016/b978-0-08-044894-7.00642-4>
- 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.
- Voogt, J., Fisser, P., Tondeur, J., & van Braak, J. (2016). Using theoretical perspectives in developing an understanding of TPACK. In *Handbook of technological pedagogical content knowledge (TPACK) for educators* (pp. 33-52). Routledge.
- Voogt, J., Knezek, G., Christensen, R., & Lai, K. W. (2018). Information and communication technology and education: Meaningful change through teacher agency. *Second handbook of information technology in primary and secondary education*, 381-396.
- Wardoyo, C., Satrio, Y. D., Narmaditya, B. S., & Wibowo, A. (2021). Do technological knowledge and game-based learning promote students achievement: lesson from Indonesia. *Heliyon*, 7(11), 1-8.
- Webb, M., & Gibson, D. (2015). Technology enhanced assessment in complex collaborative settings. *Education and Information Technologies*, 20, 675-695.
- Yeh, Y. F., Chien, S. P., Wu, H. K., & Hsu, Y. S. (2015b). Rubrics of TPACK-P for teaching science with ICTs. In *Development of Science Teachers' TPACK* (pp. 53-70). Springer.
- Yeh, Y. F., Hsu, Y. S., & Chien, S. P. (2015c). A rubric for science teachers' TPACK: Evaluating teachers' analytical comments to video-based questionnaire [E-Book Central]. In M. S. Khine (Ed.), *New Directions in Technological Pedagogical Content Knowledge Research* (pp. 267–287). Information Age Publishing.

- 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.
- Yeh, Y. F., Lin, T. C., Hsu, Y. S., Wu, H. K., & Hwang, F. K. (2015a). Science teachers' proficiency levels and patterns of TPACK in a practical context. *Journal of Science Education and Technology*, 24(1), 78-90.
- Yildirim, H. I., & Sensoy, O. (2018). The Effect of Science Teaching Enriched with Technological Applications on the Science Achievements of 7th Grade Students. *Journal of Education and Training Studies*, 6(9), 53-68.
- Yin, R. (2015) *Case Study Research: Design and Methods*, 5th Edition, SAGE Publications.
- Zovko, V. (2016). ICT-Enabled Education – Need for Paradigm Shift. *Croatian Journal of Education*, 18(2), 145–155.
<https://doi.org/10.15516/cje.v18i0.2175>

APPENDICES

A. OBSERVATION PROTOCOL

Teacher pseudonym		Date of the class	... / ... / 202.
Grade and name	7- ...	Time of record	.. : .. - .. : ..
Number of students		Topic/Subtopic	
Focus of the observation related to ICT use	Time stamp	Detail of the observation	
Assessment			
Learner			
Subject Content			
Curriculum Design			
Practical Teaching			
Other noteworthy points			

B. THE RUBRIC USED TO ASSESS TPACK-P PROFICIENCY LEVELS

The rubric used to assess TPACK-P proficiency levels

Name of Category	Name of Subcategory	Name of Proficiency Level		
		Level 1: Lack of use*	Level 2: Simple adoption*	Level 3: Infusive application* Level 4: Reflective application*
ASSESSMENT	Understanding Students' Learning Needs	<i>Unable to use ICT effectively:</i> Teacher is unable to use any ICTs to probe students' knowledge	<i>Using basic ICT tools:</i> Teacher uses ICTs as probing tools (i.e., information presentation) when trying to understand students' knowledge and/or facilitate their learning	<i>Observing students' ICT interactions:</i> Teacher observes students' learning characteristics from their interactions with ICTs. Teacher's instruction is designed and enacted based on students' learning characteristics <i>Using LMS for understanding and structuring self-learning:</i> Teacher uses the learning management systems (LMS) to understand students and engage student-centered, ICT-infused instruction to let students self-construct their learning
	Assessment Practices	<i>No use of ICT:</i> Teacher is unable to use any ICTs to assess students' learning	<i>Using ICT for in-class formative assessment:</i> Teacher evaluates students' learning with formative assessments that are implemented with ICTs (e.g., multimedia)	<i>Using comprehensive ICT tools enabling product/model design:</i> Teacher utilizes ICT-infused assessments that engage students in demonstrating their scientific thinking abilities and constructing models through technology-enhanced evaluations

The rubric used to assess TPACK-P proficiency levels (continued)

PLANNING AND DESIGNING	Planning the Class	<i>Non-ICT goal setting:</i> Teacher sets goals for teaching that are not specifically tied to the use of ICT tools	<i>Using ICT to support teaching:</i> Teacher arranges ICTs to support teacher's instruction, helping students to achieve benchmark learning goals	<i>Using multiple ICTs to support learning of and about science:</i> Teacher designs ICT-infused curricula as tasks that encourage students to do scientific explorations or concept construction
	ICT Representations	<i>Non-ICT representations:</i> Teacher uses traditional representations (e.g., drawing) to present target concepts	<i>Visualization and motivation enhancement:</i> Teacher uses ICTs to present scientific concepts that are abstract, dynamic, and micro- or macroscopic for students to visualize	<i>Scientific exploration support:</i> Teacher designs/engages learning tasks that are infused with ICT representations or instruments for students to do virtual experiments or scientific explorations
	Teaching Method/Technique	<i>Completely teacher-centered:</i> Teacher embraces chalk-and-talk lecture when implementing ICTs in class (e.g., lecturing)	<i>Mainly teacher-centered:</i> Teacher embraces pedagogical strategies that increase students' motivations and understanding of the content when using ICTs in instruction (e.g., questioning)	<i>Completely student-centered:</i> Teacher embraces pedagogical strategies to help students personally or collaboratively accomplish ICT-infused learning tasks (e.g., inquiry)

The rubric used to assess TPACK-P proficiency levels (continued)

ENACTMENT	ICT Guidance	Insufficient guidance: Teacher offers unclear instruction guiding students to understand or manipulate ICTs	Verbal and visual instruction: Teacher uses understandable language to explain the target scientific concepts with ICT implementations, but greater coherence or logic needed	Learning facilitation with practice: Teacher uses comprehensive, learning-facilitated language to conceptualize the target scientific concepts with ICT implementations	Extensive scientific thinking and concept building: Teacher is responsive to students' learning needs with explicit, thought-provoking guidance, when helping students construct the target scientific concepts with ICT implementations
	Struggling with Technical Issues	Unable to proceed with the Topic/Class: Teacher is unable to continue the course	Inadequate technical troubleshooting and backup strategies: Teacher has no backup plans or is unable to solve technical problems (i.e., implies she/he may go back to chalk-and-talk lectures)	Seeking spontaneous ICT-based solutions or delaying: Teacher engages solutions or alternatives that are technologically based (i.e., posts e-files for students to download after school)	Continuing the class calculatedly without interrupting: Teacher demonstrates her/his competence in troubleshooting without interrupting courses (e.g., prepares hard copies for Internet troubles)
	Infusing ICTs into Teaching Contexts	Belief in no contribution of ICT to teaching practices: Teacher thinks technology does not contribute to teaching practices.	Enhancing teaching through basic and convenient ICT integration: Teacher uses convenient ICTs only to make teaching more interesting and better supported	Flexible and selective management of ICTs for student learning and instructional management: Teacher manages ICTs flexibly and selectively to assist students' learning and teachers' instructional management	Skillful use of technology to support student independent learning: Teacher uses technology skillfully to assist instructional material creation and student independent learning

* Each subcategory's levels were designated with descriptive names by the researcher to improve comprehensibility. These designations are presented in bold and italic within the table

C. INTEVIEW PROTOCOL (IN TURKISH)

Görüşme Soruları

A. Öğrencileri anlama ve Öğrencileri değerlendirme

A.1. Öğrencilerinizin belirli bir fen konusunda ön bilgilerini belirleme, olası kavram yanlışlarını ortaya çıkarma gibi durumlar için BİT araçlarını nasıl kullanırsınız?

A.1.1. Sonda 1: Hangi araçları kullanırsınız?

A.2. Belirli bir konuda öğrencilerin konuyu öğrenmede yaşadıkları zorlukların belirlenmesinde BİT araçlarından yararlanmanız size nasıl fayda sağlamaktadır?

A.3. Farklı öğrenme stillerine (görsel, işitsel, uygulamalı vb.) sahip olan öğrencilerin ihtiyaçlarını karşılayabilmek için ne tür teknoloji tabanlı ders içerikleri kullanırsınız?

A.3.1. Sonda 1: Hazır platformlardan (Morpa, EBA) kullandıklarınız nelerdir?

A.3.2. Sonda 2: Klasik teknolojilerden (Office, projeksiyon cihazı vs.) kullandıklarınız nelerdir?

A.4. Teknoloji tabanlı değerlendirme yöntemlerinden ya da araçlarından aklınıza gelen örnekleri söyleyebilir misiniz?

A.4.1. Sonda 1: Bunlardan kullanabildikleriniz var mı?

A.4.2. Sonda 2: Kendiniz BİT araçları ile değerlendirme araçları tasarlamısınız?

A.4.3. Sonda 3: Varsa örnek verir misiniz? Yoksa sizce bunun nedeni nedir?

A.5. BİT araçlarını kullanarak öğrencilerinizin başarılarını ve öğrenme süreçlerinin değerlendirmesini nasıl yapıyorsunuz?

A.5.1. Sonda 1: Öğretim süreçleri boyunca (formatif) yaptığınız değerlendirmelerde BİT araçlarından nasıl yararlanıyorsunuz?

A.5.2. Sonda 2: Öğretim süreci sonunda (sumatif) yaptığınız değerlendirmelerde BİT araçlarından nasıl yararlanıyorsunuz?

A.6. Sizce teknoloji tabanlı değerlendirme yöntemleri geleneksel değerlendirme yöntemlerinden nasıl farklı olduğunu düşünüyorsunuz?

B. Planlama ve Tasarlama

B.1. Belirli bir fen konusunu öğrenme süreci için BİT araçlarını kullanmak ne kadar önemlidir?

B.1.1. Sonda 1: Tasarladığınız bir dersin içeriğindeki bilgileri öğrencilerinize daha iyi kavratmak için BİT kullanmanın etkisini nasıl görüyorsunuz?

B.2. BİT araçlarını kullandığınız bir dersi nasıl planlıyorsunuz?

B.2.1. Sonda 1: Hangi fen konularının öğretiminde BİT kullanımının daha uygun olduğuna nasıl karar veriyorsunuz?

B.3. Yıllık planları ve/veya günlük ders planları oluştururken teknoloji tabanlı dersler planlama konusundaki deneyimleriniz nelerdir?

B.4. BİT tabanlı olarak yıllık planlarınızı veya derslerinizi planlarken ne tür faktörleri göz önünde bulundurursunuz?

B.4.1. Sonda 1: BİT tabanlı ders tasarlarken müfredat (program) hedefleri, öğrenci öğrenmeleri gibi ya da sizin göz önünde bulundurduğunuz başka önemli noktalar nelerdir? Bunlara niçin önem veriyorsunuz?

B.5. Derslerinizde kullandığınız veya kullanmayı planladığınız BİT araçlarından bahseder misiniz?

B.5.1. Sonda 1: Dersiniz için en uygun BİT araçlarının hangisi olduğuna neye göre karar verirsiniz?

B.5.2. Sonda 2: Bu derslerde öğrencilerinizde ulaşmayı beklediğiniz amaçlar neler oluyor?

B.5.3. Sonda 3: Bu derslerinizde öğrencilerin neler yapmasını/kazanmasını bekliyorsunuz?

B.6. BİT tabanlı öğretimlerinize uygun öğretim yöntemleri/teknikleri/stratejileri neler oluyor?

B.6.1. Sonda 1: Bu söylediğiniz yöntem/tekniklerin uygunluğuna nasıl karar verdiniz?

B.6.2. Sonda 2: Bu söylediğiniz yöntem/teknikleri nasıl tasarladığınıza birkaç örnek söyleyebilir misiniz?

C. Öğretim uygulamaları

C.1. Belirli bir fen konusunu öğretirken BİT araçları kullanmak dersin performansını nasıl etkiliyor?

C.1.1. Sonda: Teknoloji kullanmadan işlediğiniz bir dersinizden farklı olduğunu düşünüyor musunuz?

C.2. Belirli bir fen konusunu öğretirken BİT araçları kullanmak öğrencilerinizin öğrenme performansını nasıl etkiliyor?

C.2.1. Sonda: Teknoloji kullanmadan işlediğiniz bir dersinizden farklı olduğunu düşünüyor musunuz?

C.3. Belirli bir fen konusunu öğretirken BİT araçları kullanmak öğrencilerinizin motivasyonunu nasıl etkiliyor?

C.3.1. Sonda: Teknoloji kullanmadan işlediğiniz dersten farklı olduğunu düşünüyor musunuz?

C.4. Öğretim sürecinde BİT araçlarını kullanmanın dezavantajları olup olmadığı hakkında ne düşünüyorsunuz?

C.5. BİT tabanlı işlediğiniz bir dersinizde karşılaştığınız teknik problemlerle (donanım, yazılım vb.) nasıl başa çıkıyorsunuz?

C.5.1. Sonda: Böyle beklenmedik durumlar için bir B planı (alternatif etkinlik) düşünür müsünüz?

C.6. Belirli bir fen konusunu öğretme sürecinizde kullandığınız BİT araçları sizin öğretim yönetiminizi nasıl etkilediğine örnekler verebilir misiniz?

C.6.1. Sonda: BİT araçları sizin öğretim sürecinizi yürütmenizde ve denetlemenizde nasıl bir rol oynuyor?

D. CODING TABLE FOR PROFICIENCY LEVELS

The coding table for proficiency levels

Category	Subcategory Code	Definition
ASSESSMENT	Understanding Student Learning Needs	Teachers' varying abilities and methods of using ICT to assess their students' learning requirements
	Unable to use ICT effectively	Teacher lacks the ability to effectively employ any ICT tools for assessing students' knowledge or facilitating their learning
	Using basic ICT tools	Teacher utilizes ICT tools primarily for information presentation and as tools to understand students' knowledge or support their learning
	Observing students' ICT interactions	Teacher observes students' learning characteristics by analyzing their interactions with ICT resources
	Using LMS for understanding and structuring self-learning.	Teacher effectively employs LMS to gain insights into students' needs and employs student-centered, ICT-integrated instruction that enables students to construct their own learning experiences
	Assessment Practices	Teacher's diverse ICT-based formative assessment practices for gauging student learning
	No use of ICT	Teacher lacks the ability to employ ICT tools for assessing students' learning
	Using ICT for in-class formative assessment	Teacher uses ICT tools to assess students' learning through in-class formative assessments
	Using ICT for out-of-class formative assessment	Teacher assesses students' learning using electronic assessment systems that provide responsive feedback or maintain learning records
	Using comprehensive ICT tools enabling product/model design	Teacher employs ICT-infused assessments that prompt students to demonstrate their scientific thinking abilities and construct models through technology-enhanced evaluations

The coding table for proficiency levels (continued)

PLANNING AND DESIGNING	Planning the class	Teacher's preparation and organization of instructional activities, including setting goals and utilizing ICTs to support teaching and learning
	non-ICT goal setting	Teacher sets instructional goals not dependent on ICT tool use
	Using ICT to support teaching	Teacher employs ICT tools to support instruction in achieving benchmark learning objectives
	Using multiple ICTs to support learning science	Teacher integrates various ICT applications to enhance students' conceptual comprehension and address misconceptions
	Using multiple ICTs to support learning of and about science	Teacher designs ICT-infused curricula as tasks that encourage students to both engage in scientific explorations and construct scientific concepts
	ICT Representations	Teacher's incorporation of various ICT representations to enhance science instruction
	non-ICT representations	Teacher employs traditional representations instead of ICT representations to convey scientific concepts
	Visualization and motivation enhancement	Teacher leverages ICTs to present abstract and dynamic scientific concepts to enhance students' visualization and motivation
	Interactive learning support	Teacher encourages students to actively engage with ICT-infused representations and instruments during the conceptualization of scientific concepts
	Scientific exploration support	Teacher integrates ICT representations into learning tasks to guide students in conducting virtual experiments, exploring scientific phenomena, and developing science process skills
	Teaching method/technique	Teacher's instructional strategies with varying degrees of student-centeredness when using ICTs
	Completely teacher-centered	Teacher employs traditional lecture-style instruction, primarily relying on one-way communication when integrating ICTs (e.g., lecturing)
	Mainly teacher-centered	Teacher combines pedagogical strategies aimed at enhancing student motivation and understanding of the content when incorporating ICTs, allowing for some interaction with students but with the teacher still leading (e.g., questioning)
	Mainly student-centered	Teacher utilizes pedagogical approaches that shift the focus toward students' comprehension and discussions of the target concepts during ICT-assisted learning, encouraging active involvement and participation (e.g., virtual experiments)
	Completely student-centered	Teacher employs pedagogical strategies focused on enabling students to take the lead and actively participate, individually or collaboratively, in ICT-infused learning tasks (e.g., inquiry)

The coding table for proficiency levels (continued)

ENACTMENT	ICT guidance	Teacher's guidance quality in utilizing ICT for science instruction
	Insufficient guidance	Teacher offers vague or unclear instruction when guiding students to understand or manipulate ICTs
	Verbal and visual instruction	Teacher provides understandable language and visual aids to explain scientific concepts with ICTs but requires more logical coherence
	Learning facilitation with practice	Teacher employs comprehensive language that enhances learning and facilitates the conceptualization of scientific concepts using ICT
	Extensive scientific thinking and concept building	Teacher offers explicit, thought-provoking guidance, responding to students' learning needs, to help them construct scientific concepts with ICT implementations
	Struggling with technical issues	Teacher's handling of technical challenges during ICT-based science instruction
	Unable to proceed with the Topic/Class	Teacher faces insurmountable technical difficulties that prevent continuing the lesson, leading to potential disruptions
	Inadequate technical troubleshooting and backup strategies	Teacher lacks backup plans and struggles to resolve technical problems, possibly resulting in reverting to traditional teaching methods
	Seeking spontaneous ICT-based solutions or delaying	Teacher attempts to address technical issues with ad-hoc ICT solutions or postpones aspects of the lesson by providing electronic materials for students to access after the class
	Continuing the class calculatedly without interrupting	Teacher efficiently troubleshoots technical problems without interrupting the class by, for example, having physical copies of materials as backup in case of internet issues
	Infusing ICTs into teaching contexts	Teacher's strategic integration of ICT tools during instruction for enhancing the learning environment
	Belief in no contribution of ICT to teaching practices	Teacher holds the belief that technology does not offer support for teaching
	Enhancing teaching through basic and convenient ICT integration	Teacher utilizes easily accessible ICT tools to enhance classroom instruction and engage students effectively
	Flexible and selective management of ICTs for student learning and instructional management	Teacher adeptly manages ICT tools, selectively employing them to enhance student learning and support instructional methods as needed
	Skillful use of technology to support student independent learning	Teacher skillfully employs technology to facilitate the creation of instructional materials and promote independent learning among students

E. CODING TABLE FOR INTERPLAYS AMONG TPACK-P COMPONENTS

The coding table for interplays among TPACK-P components

Category	Subcategory Code	Definition
KoA	ICT-based assessment awareness	Teacher's knowledge of various digital assessment methods and their applicability for the lesson
	Assessment based on ICT-based product development	Teacher's utilization of an assessment method focusing on students' creation of tangible digital products to evaluate their understanding and skills
	In-class formative assessment using ICT	Teacher's implementation of ongoing assessments with the assistance of ICT tools during regular class sessions
	Out-class formative assessment using ICT	Teacher's utilization of ICT tools to conduct digital assessments outside of regular class sessions
KoL	Awareness of students' learning difficulties with ICT	Teacher's effort to employ ICT tools for identifying and addressing students' learning difficulties during the learning process
	Identifying students' misconceptions using ICT	Teacher's skill in using ICT to recognize and address students' misconceptions related to the subject matter
	Adapting to students' learning styles with ICT	Teacher's ability to use ICT tools to recognize the diverse learning preferences and tendencies of students
	Checking students' background knowledge using ICT	Teacher's ability to employ ICT for assessing students' prior knowledge and tailoring instruction accordingly
	Recognizing ICT-based motivational strategies for students	Teacher's awareness of strategies that employ ICT to motivate and engage students in the learning process
KoSC	Paying attention to content-ICT tool appropriateness	Teacher's awareness of the relevance and suitability of ICT tools to the subject content being taught
	Facilitating Understanding of the Content	Teacher's strategies and practices to make use of ICT tools to enhance students' comprehension and grasp of the subject content

The coding table for interplays among TPACK-P components (continued)

KoCD	Factors affecting the ICT-based design	Teacher's awareness of the factors that impact the integration of ICT in curriculum design
	ICT access	Teacher's recognition of the availability and accessibility of ICT resources for students
	Level of achievement	Teacher's consideration of students' performance levels when planning an ICT-integrated curriculum
	Demographic structure	Teacher's understanding of how the demographic characteristics of their students can influence curriculum design with ICT
	Student satisfaction	Teacher's regard for students' contentment and motivation, influencing the inclusion of technology-related elements in the curriculum
	Subject content	Teacher's knowledge of how the specific subject matter affects the design of an ICT-integrated curriculum
	Peer cooperation	Teacher's inclination for collaborative discussions with fellow educators when making curriculum design decisions
	ICT-based learning tasks	Teacher's implementation of technology-infused learning activities to engage students with ICT tools while aiming to achieve specific learning objectives
	Establishing relationship between concepts	Teacher's ability to connect and relate various scientific concepts within the curriculum
	Using science process skills	Teacher's encouragement of students to use basic and integrated science process skills, such as observing, measuring, formulating hypotheses, and controlling variables
	Designing model/product	Teacher's integration of model or product development tasks into the curriculum
	ICT-infused course design purpose	Teacher's intentions in designing the lesson with technology integration to meet specific objectives
	Science program goals	Official learning objectives of science course outlined in the science program curriculum
	Hidden program goals	Additional, undisclosed objectives beyond official learning objectives of science course

The coding table for interplays among TPACK-P components (continued)

KoCD	ICT-Integrated Teaching Methods/Techniques	Teacher's instructional approaches that incorporate ICT tools during science class
	Educational game	Teacher's utilization of educational games as part of the teaching strategy that makes use of ICT to engage and instruct students.
	Concept map	Teacher's incorporation of concept mapping, which is a visual representation of ideas and their connections using ICT
	Lecturing	Teacher's conventional teaching method that involves a teacher delivering content to students through spoken communication
	Guided lecturing	Teacher's primarily leading of instruction and presentation of the main content but periodically involving students through questions, discussions, or short activities
	Questioning	Teacher's application of question-answer session to stimulate student thinking, encourage participation, and foster discussions during lessons
	Virtual experimenting	Teacher's use of e-experiments to engage students in simulated scientific experiments, promoting interactive learning experiences to explore and understand scientific concepts
	ICT Representation used in teaching	Teacher's employment of various digital formats and materials to enhance teaching and facilitate student learning
	Digital textbook/enriched e-book	Teacher's integration of digital versions of textbooks or digitized resources enriched with multimedia elements like audio recordings, videos, and images (z-book)
	Digital lecture notes	Teacher's use of digital lecture notes as part of the instructional content for teaching and learning
	Drawing	Teacher's creation of digitally created materials through ICT tools to convey scientific concepts as part of the teaching and learning process
	Interactive experiment	Teacher's utilization of interactive experiments to actively engage students in hands-on learning and exploration of scientific concepts
	Picture/Photo	Teacher's use of pictures or photographs to visually represent and illustrate scientific concepts
	Simulation	Teacher's employment of simulations or virtual models to replicate real-world scientific phenomena for instructional purposes
	Animation	Teacher's incorporation of animations to present dynamic and complex scientific concepts in a more visually engaging and understandable manner
	Video	Teacher's use of videos to convey scientific concepts and support teaching and learning

The coding table for interplays among TPACK-P components (continued)

KoPiT	Struggling with ICT Use	Teacher's difficulties and challenges when incorporating ICT into teaching practices
	Adapting to ICT tools or applications	Teacher's flexibility in incorporating, conditioning, and adjusting the use of ICT tools or applications to ensure effective integration into the curriculum
	ICT Guidance	Teacher's provision of clear and effective guidance to students on how to use ICT tools in the learning process.
	Encouraging student use of ICT	Teacher's practices aimed at motivating and empowering students to actively and effectively engage with ICT tools
	Guiding students to learn using ICT	Teacher's role in assisting and directing students in their use of ICT for educational purposes
	Instructional Management with ICT	Teacher's strategies and practices in utilizing ICT tools for the organization, delivery, and assessment of instructional content
	Achieving Target Learning Goals	Teacher's efforts to align the use of ICT with specific educational objectives and desired learning outcomes
	Managing the Classroom	Teacher's ability to maintain discipline, structure, and a contributory learning environment while integrating ICT
	ICT Advantages/Disadvantages	Teacher's awareness and recognition of the benefits and limitations of ICT in the teaching and learning process
	Saving Time and Effort	Teacher's use of ICT to facilitate administrative tasks and reduce the workload associated with teaching

F. APPROVAL OF METU RESEARCH CENTER FOR APPLIED ETHICS

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
ueam@metu.edu.tr
www.ueam.metu.edu.tr

Sayı: 28620816 / 368

29 EYLÜL 2021

Konu : Değerlendirme Sonucu

Gönderen: ODTÜ İnsan Araştırmaları Etik Kurulu (İAEK)

İlgi : İnsan Araştırmaları Etik Kurulu Başvurusu

Sayın Elvan ŞAHİN

Danışmanlığını yürüttüğünüz Murat Berat UÇAR'ın "Ortaokul Fen Bilimleri Öğretmenlerinin Tıbb-Pratik Yeterlilik Seviyelerinin ve Tıbb-Pratik Bileşenleri Arasındaki Etkileşimin Doğasının Keşfedilmesi" başlıklı araştırması İnsan Araştırmaları Etik Kurulu tarafından uygun görülmüş ve **368-ODTU-2021** protokol numarası ile onaylanmıştır.

Saygılarımızla bilgilerinize sunarız.



Dr.Öğretim Üyesi Şerife SEVİNÇ
İAEK Başkan Vekili

G. APPROVAL OF PROVINCIAL DIRECTORATE OF NATIONAL EDUCATION



T.C.
KİLİS VALİLİĞİ
İl Milli Eğitim Müdürlüğü

Sayı : E-21722023-605.01-58643712
Konu : Veri Toplama ve Anket İzni

22/09/2022

VALİLİK MAKAMINA

İlgi : a) Milli Eğitim Bakanlığı Yenilik ve Eğitim Teknolojileri Genel Müdürlüğünün 21.10.2021 tarih ve 2020/2 nolu genelgesi
b) Kilis 7 Aralık Üniversitesi Genel Sekreterliğinin 26.10.2021 tarih ve 7772 sayılı yazısı.

Kilis 7 Aralık Üniversitesi Genel Sekreterliğinin ilgi (b) yazısında Orta Doğu Teknik Üniversitesi İlköğretim Bölümü doktora eğitimi kapsamında; Muallim Rıfat Eğitim Fakültesi Dekanlığı Matematik ve Fen Eğitim Bölümü Fen Bilgisi Ana Bilim Dalı öğretim elemanı Arş.Gör. Murat Berat UÇAR tarafından hazırlanan "Ortaokul Fen Bilimleri Öğretmenlerinin Tıbbi-pratik Yeterlilik Seviyelerinin Tıbbi-pratik Bileşenleri Arasındaki Etkileşim Doğasının Keşfedilmesi" konulu doktora tez çalışmasının ilimizdeki ortaokullarda yapılması talep edilmektedir.

Konu ile ilgili belgelerin ve anket sorularının incelenmesi neticesinde, yukarıda adı geçen araştırma çalışmasının Milli Eğitim Bakanlığı Yenilik ve Eğitim Teknolojileri Genel Müdürlüğünün ilgi (a) genelgesine uygun olarak düzenlendiği anlaşılmış olup, Kilis 7 Aralık Üniversitesi Muallim Rıfat Eğitim Fakültesi Dekanlığı Matematik ve Fen eğitim Bölümü Fen Bilgisi Ana Bilim Dalı öğretim elemanı Arş.Gör. Murat Berat UÇAR tarafından söz konusu araştırmanın müdürlüğümüze bağlı ortaokullarda yapılması müdürlüğümüzce uygun görülmektedir.

Makamlarınızca da uygun görülmesi halinde olurlarınıza arz ederim.

Mehmet Emin AKKURT
İl Milli Eğitim Müdürü

OLUR
Kemal BALABAN
Vali a.
Vali Yardımcısı

EKLER :
1-İlgi Yazı
2-Genelge

Bu belge güvenli elektronik imza ile imzalanmıştır.

Adres : Akpınar Cad.İl Milli Eğitim Müd. Kat:1 79100-KİLİS

Belge Doğrulama Adresi : <https://www.turkiye.gov.tr/meb-ebys>

H. INFORMED CONSENT FORM (IN TURKISH)

GÖNÜLLÜ KATILIM FORMU

Bu araştırma, ODTÜ İlköğretim Bölümü Doktora öğrencisi ve Kilis 7 Aralık Üniversitesi Eğitim Fakültesi araştırma görevlisi Murat Berat Uçar tarafından Orta Doğu Teknik Üniversitesi Eğitim Fakültesi öğretim üyesi Doç. Dr. Elvan Şahin danışmanlığındaki doktora tezi kapsamında yürütülmektedir. Bu form sizi araştırma koşulları hakkında bilgilendirmek için hazırlanmıştır.

Çalışmanın Amacı Nedir?

Bu araştırmanın amacı fen bilimleri öğretmenlerinin derslerinde eğitim teknolojilerini nasıl bütünleştirerek derslerini işledikleri, öğrencilerin öğrenmelerini geliştirmek için ne tür eğitim teknolojilerinden ve araçlarından nasıl yararlandıklarını derinlemesine araştırmaktır.

Nasıl Yardımcı Olacaksınız?

Öncelikle, sizden teknoloji tabanlı işlediğiniz fen bilimleri dersi ünitesinin/konusunun/dersinin planlanması, yürütülmesi ile teknoloji entegrasyonunu nasıl yaptığınızla ilgili bir görüşme yapmak istiyorum. Yaklaşık 60 dakika olmasını beklediğim bu görüşme içerisinde bir dizi soru yöneltip yanıtlarınızı ses kayıt cihazı ile kaydetmek istiyorum. Daha sonra işleyeceğiniz bu üniteye derslerinizi bir kısmını sizi ve öğrencilerinizi rahatsız etmeyecek şekilde video kayıt altına almak istiyorum.

Sizden Topladığım Bilgileri Nasıl Kullanacağım?

Araştırmaya katılımınız tamamen gönüllülük temelinde olmalıdır. Çalışmada sizden kimlik belirleyici hiçbir bilgi istenmemektedir. Cevaplarınız tamamıyla gizli tutulacak ve sadece benim tarafından incelenecektir. Katılımcılardan elde edilecek bilgiler toplu halde değerlendirilecek ve bilimsel yayımlarda kullanılacaktır.

Katılımınızla ilgili bilmeniz gerekenler:

Araştırma Milli Eğitim Bakanlığı'nın ve okul yönetiminin izni ile gerçekleşmektedir. Araştırma uygulamasına katılım tamamıyla gönüllülük esasına dayalıdır. Çalışmada sizden kimlik belirleyici hiçbir bilgi istenmemektedir. Uygulamalar, kişisel rahatsızlık verecek sorular ve durumlar içermemektedir. Ancak, katılım sırasında sorulardan ya da herhangi başka bir nedenden rahatsız hissederseniz cevaplama işini yarıda bırakabilirsiniz.

Araştırmayla ilgili daha fazla bilgi almak isterseniz:

Katılımı onaylamadan önce sormak istediğiniz herhangi bir konu varsa sormaktan çekinmeyiniz. Çalışma bittikten sonra bana ulaşarak soru sorabilir, sonuçlar hakkında bilgi isteyebilirsiniz. Çalışma hakkında daha fazla bilgi almak için [REDACTED]@metu.edu.tr adresinden iletişim kurabilirsiniz.

Yukarıdaki bilgileri okudum ve bu çalışmaya tamamen gönüllü olarak katılıyorum.

(Formu doldurup imzaladıktan sonra uygulayıcıya geri veriniz).

Adı Soyadı

Tarih

İmza

---/---/----

İ. CURRICULUM VITAE

PERSONAL INFORMATION

Surname, Name: Uçar, Murat Berat

EDUCATION

Degree	Institution	Year of Graduation
PhD	METU Elementary Education	2024
MS	Firat University Science Education	2015
BS	METU Elementary Science Education	2010

WORK EXPERIENCE

Year	Place	Enrollment
2015- Present	Kilis 7 Aralık University Department of Mathematics and Science Education	Research Assistant
2011-2015	Dicle University Department of Elementary Education	Research Assistant

LANGUAGES

Advanced English, Native Turkish

PUBLICATIONS

Uçar, M. B., & Uçar, F. M. (2022). Her zaman doğa: Çevresel sürdürülebilirlik ve çocuk. In N. Darıca & Z. Mercan (Eds.), *Erken çocuklukta doğa eğitimi* (1st

ed., pp. 139–168). Eđiten Kitap.

Aronowitz, S. (2021). Kesinliđin öküşü: Modern Fiziđin Tarihi ve Felsefesi (M. Açıkyıldız & **M. B. Uçar**, Trans.). In F. Bektaş & E. Karadađ (Trans. Eds.), *İktidar biçimi olarak bilim: Modern toplumda söylem ve ideoloji* (pp: 207-234). Vizetek. (Original work published in 1988).

Uçar, M. B. & Canpolat, E. (2019). Modelling Preservice Science Teachers' Environment-Friendly Behaviours. *Australian Journal of Teacher Education*, 44(2), 1-14. <https://doi.org/10.14221/ajte.2018v44n2.1>

Uçar, M. B. & Sahin, E. (2018). Pre-service Science Teachers' Discrimination Level of Science and Pseudoscience. *Science Education International*, 29(4), 267-273. <https://files.eric.ed.gov/fulltext/EJ1205432.pdf>

Uçar, M. B. & Sahin, E. (2018). A Review on Assessment of Technological Pedagogical Content Knowledge for Pre-Service Science Teachers. In *Proceedings of the 27th International Congress on Educational Sciences*, 2099-2108. <https://doi.org/10.14527/9786052414743>

Uçar, F. M., **Uçar, M. B.**, & Caliskan, M. (2017). Investigation of Gifted Students' Problem-Solving Skills. *Journal for the Education of Gifted Young*, 5(3), 1-14. <http://dx.doi.org/10.17478/JEGYS.2017.61>

Akuzum, C., **Uçar, M. B.**, & Hidirođlu, F. M. (2015). Preservice Science Teachers Views on The Traineeship Applications. *Journal of Computer and Education Research*, 3(5), 144-165.

Akuzum, C. & **Uçar, M. B.** (2015). Self-Efficacy and Concerns of Preservice Teachers towards Social Media Use as an Educational Tool. *Mevlana International Journal of Moral and Values Education*, 2(1), 38-54

Uçar, M. B., Demir, C., & Hiđde, E. (2013). Exploring the Self-Confidence of Preservice Science and Physics Teachers towards Technological Pedagogical Content Knowledge. In *Proceedings of the 5th World Conference on Educational Sciences*, 116, 3381-3384. <https://doi.org/10.1016/j.sbspro.2014.01.768>

Hiđde, E., **Uçar, M. B.**, & Demir, C. (2013). The investigation of self-efficacy of Pre-service Science Teachers and Pre-service Physics Teachers towards Web Pedagogical Content Knowledge regarding Internet Use Habits. In *Proceedings of the 5th World Conference on Educational Sciences*, 116, 3395-3399. <https://doi.org/10.1016/j.sbspro.2014.01.771>



J. TURKISH SUMMARY / TRKE ZET

1. Giriř

Son birkaç on yılda, dünya genelinde teknoloji aracılığıyla bilgi edinme ve paylaşma hızla artmıştır. Bu deęişim, eğitimcileri, politika yapıcılar ve toplumları, bu evrilen manzaraya nasıl adapte olacakları konusunda deęerlendirme yapmaya yönlendirmiştir. Bu bağlamda, eğitimcilerin odak noktası, öğrencileri teknolojinin gücünü etkili bir şekilde kullanmaya hazırlamak ve öğretmenlere bu teknolojiyi öğretim pratięine sorunsuz bir şekilde entegre etme becerilerini kazandırmak olmuştur (Jhurree, 2005). Bu çift amaç, öğretmenlerin dijital yeterliliklerinin gelişimine bağlıdır.

Teknolojinin eğitime entegrasyonu, anlama, hatırlama, eleştirel düşünme, yaratıcılık ve problem çözme becerilerini artırma potansiyeli nedeniyle önemlidir (Evawati ve Susilowati, 2023; Ismajli vd., 2020; Koh vd., 2015). Ancak, bu potansiyeli gerçekleştirmek, teknolojinin sınıf içinde etkili bir şekilde kullanılmasına bağlıdır (Dilworth vd., 2012). Bu nedenle, öğretmenlere teknoloji araçları ve uygulamalarını öğretim pratięine sorunsuz bir şekilde entegre etme bilgi ve becerisi kazandırmak giderek daha fazla vurgulanmaktadır.

Eğitim paydařlarının teknolojinin sınıflara entegrasyonunu giderek vurgulaması, öğretmenlerin teknolojiyi kullanma kapasitesini zorlu bir sorun haline getirir (Culp vd., 2005). Bu zorluk, içerik, pedagoji ve teknoloji arasındaki etkileşimleri araştırmaya sevk etmiştir. Bilim öğretimine teknoloji entegrasyonunun sürekli zorluklarına dair, öğretmenlerin bu konudaki yeterliliklerini tanımlayan kapsamlı bir modelin eksikliği pek çok araştırmacı tarafından vurgulanmıştır (Graziano vd., 2017; Mishra ve Koehler, 2006; Yeh vd., 2014).

Bu zorluęa yanıt olarak, Mishra ve Koehler (2006), Shulman'ın Pedagojik Alan Bilgisi (PAB) modelinden türetilmiş olan Teknolojik Pedagojik Alan Bilgisi (TPAB) çerçevesini tanıtmıştır. Shulman'ın çalışması, PAB'in (Carlsen, 1999) önemli rolünü tanıyarak öğretmen eğitiminde paradigma deęişikliğine yol açmıştır.

TPAB'ın öğretmen eğitimindeki devrim niteliğindeki potansiyeli, uygulamalarına dair evrimleşen bir perspektif ile birlikte gelir. Yeh vd. (2014) tarafından geliştirilen TPAB-P gibi modellerin ortaya çıkması, öğretmenlerin TPAB'ını pratik öğretim ortamlarında değerlendirmenin önemini vurgulamaktadır. TPAB-P, önceki TPAB çalışmalarından farklılaşarak öğretmenlerin sadece pedagojik, alan ve teknoloji bilgilerinin bileşimini değil, aynı zamanda gerçek öğretimdeki yeteneklerini değerlendirmeye odaklanmaktadır.

Küresel trendlere uygun olarak, Millî Eğitim Bakanlığı (MEB), Türkiye'de teknoloji entegrasyonunu ilerletmek için aktif bir şekilde girişimlerde bulunmaktadır. Örneğin, 2012 yılında başlatılan FATİH Projesi, öğretmenleri eğitim teknolojisini eğitimin çeşitli yönlerine entegre etmeye teşvik etmeyi amaçlamakta ve eğitim teknolojisinin etkili bir şekilde uygulanmasında öğretmen yeterliliğinin çok önemli bir rolü olduğunu vurgulamaktadır. Ancak, ulusal çabalara rağmen, Türkiye'deki fen bilimleri öğretmenleri teknoloji entegrasyonu sırasında bağlamsal faktörler ve düşük yeterlik düzeyi gibi çeşitli zorluklarla sık sık karşı karşıya kalmışlardır (Cavas vd., 2009; Özden, 2007; Taş ve Balgalmış, 2016). Bu zorlukların öğretmenlerin TPAB gelişimini olumsuz etkileyebileceği göz önünde bulundurulduğunda, öğretmenlerin TPAB'ını inceleyen araştırmalar büyük önem kazanmaktadır. Mevcut çalışmalar genellikle öğretmenlerin yanıt verdiği TPAB anketlerine dayanmakta ve öğretmenlerin ve öğretmen adaylarının öğretimsel uygulamalarını derinlemesine incelememektedir (Akyüz, 2018; Ucar ve Sahin, 2018), bu da potansiyel olarak TPAB'larının doğasının kapsamlı bir şekilde anlaşılmasını engellemektedir. Bu nedenle, pratik uygulamaların derinlemesine incelenmesi yoluyla TPAB'ın doğasını araştıran, odağı kendi kendine bildirilen ölçümlerden gerçek öğretim uygulamalarından toplanan ayrıntılı bilgilere kaydıran nitel çalışmalara ihtiyaç vardır.

Ayrıca, fen bilimleri öğretmenlerinin teknoloji kullanma konusundaki bilgi ve yeteneklerinin kapsamlı bir anlayışının eksikliği, teorik bilgi ile pratik uygulama arasında bir bağlantı kopukluğuna neden olmaktadır (Jen vd., 2016). Bu zorlukları dikkate alarak, öğretmenlerin teknolojik yeterliklerinin keşfedilmesi, FATİH projesinin hedefleri ile de uyumlu hale gelmektedir. Bu bağlamda, BİT araçları kullanarak etkili fen öğretimi için gerekli TPAB yapısının derinlemesine incelenmesi, öğretmenlerin teknoloji entegrasyon çabalarındaki güçlü ve zayıf yönleri hakkında

değerli içgörüler sunmaya elverişlidir.

Eğitimde teknoloji entegrasyonu ve fen bilimleri öğretmenlerinin karşılaştığı zorluklar bağlamında kuvvet ve enerji konularının önemi ortaya çıkmaktadır. Dinamik doğaları ve fen programındaki temel rolleriyle karakterize edilen bu kavramlar, yenilikçi teknoloji tabanlı öğretim stratejileri için umut verici fırsatlar sunmaktadır. Dahası, teknoloji araçlarıyla sorunsuz entegrasyon potansiyelleri, fen bilimleri öğretmenlerinin TPAB'ını anlama ihtiyacının altını çizmektedir. TPAB'ın kuvvet ve enerji özelinde araştırılması, teknoloji entegrasyonunun süregelen zorluklarına bir yanıt olmanın yanı sıra, teknoloji ve fen eğitimi arasındaki incelikli etkileşimi çözmeye yönelik önemli bir adımdır. Dolayısıyla bu araştırma, fen eğitimi alanında teorik bilgi ile pratik uygulama arasındaki boşluğu doldurarak bu özel alanlarda etkili öğretim uygulamalarını geliştiren değerli içgörülere katkıda bulunmaktadır.

1.1. Çalışmanın Amacı ve Araştırma Soruları

Bu çalışma, hizmet içi fen bilimleri öğretmenlerinin TPAB kavramı ile ilgili iki temel araştırma hedefini gerçekleştirmeyi amaçlamaktadır. Çalışma, Yeh vd. (2014; 2015a) tarafından önerilen TPAB-P çerçevesine dayanan değerlendirme, planlama ve tasarım, öğretim uygulamaları boyutlarında fen bilimleri öğretmenlerinin yeterlilik düzeylerini keşfetmeye çalışmaktadır. Bu inceleme, öğretmenlerin teknolojiyi fen eğitiminin farklı aşamalarına nasıl entegre ettiklerinin kapsamlı bir değerlendirmesini içermekte olup öğretim ve teknoloji uzmanlığının önemine vurgu yapmaktadır.

Ayrıca, bu araştırma aynı zamanda fen bilimleri öğretmenlerinin TPAB-P çerçevesi bağlamında sahip oldukları beş TPAB-P bileşeni arasındaki karmaşık etkileşimleri incelemeyi amaçlamaktadır. Bu bileşenler, öğrenci bilgisi, konu içeriği, müfredat tasarımı, pratik öğretim ve değerlendirme bilgisini içermektedir. Bu nedenle araştırma, fen bilimleri öğretmenleri tarafından kullanılan bu bileşenler arasındaki dinamik etkileşimlerin kapsamlı bir şekilde anlaşılmasını vurgulamaktadır.

Bu çalışma, aşağıdaki araştırma sorularını ele almaktadır:

- Fen bilimleri öğretmenlerinin kuvvet ve enerji konularının öğretiminde TPAB-P yeterlilik düzeyleri nedir?

- Fen bilimleri öğretmenlerinin kuvvet ve enerji konularının öğretiminde beş TPAB-P bileşeni arasındaki etkileşimin doğası nedir?

Bu araştırma soruları, TPAB-P çerçevesi içinde yeterlilik düzeylerini ve etkileşimleri araştırmaya rehberlik eder, ortaokul sınıflarında kuvvet ve enerji konularını öğretme bağlamında fen öğretmenlerinin TPAB'ına dair içgörüler sunar.

1.2. Çalışmanın Önemi

Hızla evrilen günümüz dünyasında bilimsel ve teknolojik ilerlemeler özellikle fen bilimleri öğretmenleri için vazgeçilmez hale gelmiştir. Teknolojinin fen eğitime entegrasyonu modern okullarda bir seçenek değil, bir zorunluluk olmuştur (Szymkowiak vd., 2021). Fen bilimleri öğretmenleri sadece konu alan bilgilerinde derin bir bilgiye sahip olmakla kalmamalı, aynı zamanda TPAB yeterliliğini de sergilemesi gerekmektedir (Yeh vd., 2015a).

Bir yandan fen bilimleri öğretmenleri öğrencilere bilimsel kavramları etkili bir şekilde iletebilmek için gerekli bilgiye sahip olması gerekirken, diğer yandan da teknolojinin öğretimde kullanılması, öğrenci başarısını artırmakla ilişkilendirilmiş (Ahmad ve Hamad, 2020) ve bu da TPAB yeterliliğini öğretmenler için kritik bir özellik haline getirmiştir. Öğrencilerinin rol modelleri olan fen bilimleri öğretmenleri, kendi öğretim kalitelerini artırmada, öğrencilerin fen içeriğini öğrenmelerinde, onların BİT kullanımlarını ustalaştırmada ve onları dijital çağa hazırlamada önemli bir rol oynamaktadırlar (Tondeur vd., 2019). Bu durum, öğretmen ve öğretmen adaylarının TPAB yeterliliklerini belirlemenin, geliştirmenin ve bu alana katkıda bulunmanın aciliyetini vurgular (Koh ve Divaharan, 2011; Mandaci Sahin vd., 2013). Bu nedenle, fen bilimleri öğretmenlerinin TPAB'nın öğretim uygulamaları üzerinden karmaşık ve dinamik doğasını inceleyip analiz etmek mevcut literatürdeki TPAB tartışmalarına değerli içgörüler sunabilir.

Bu çalışma, TPAB'ı pratik bir yaklaşımla ele alarak, hizmet içi öğretmenlerin kişisel görüşlerini ele alarak ve sınıf içi öğretim uygulamalarını inceleyerek onların pratik öğretim bilgisini araştırmayı amaçlamaktadır. İlk olarak Koehler ve Mishra (2005) tarafından önerilen TPAB çerçevesi, etkili teknoloji ile entegre bir öğretim için teknoloji, pedagoji ve konu alanı arasındaki karmaşık etkileşimi ortaya koymada etkili

olmuştur. Bu bağlamda, fen bilimleri öğretmenlerinin, uygun teknolojileri ve stratejileri kullanarak TPAB'larını fen öğretimi sırasında nasıl gösterdiklerini araştırmak önem kazanmaktadır. Pratik öğretim bilgisi, öğretim deneyiminden etkilenen ve öğretmenlerin çoklu bilgi ve inançlarının karmaşık etkileşimi ile dolaylı olarak gelişen TPAB gelişiminin merkezi bir bileşenidir (Voogt vd., 2016). Sınıf içi öğretim sırasında yapılan gözlemler, bu pratik bilgiyi anlamının esaslı bir yolunu oluşturmaktadır (Yeh vd., 2014; 2015a). Dolayısıyla, bu çalışma fen bilimleri öğretmenlerinin TPAB'ının kanıta dayalı göstergeleri aracılığıyla TPAB bileşenlerinin etkileşimlerini ve etkilerini ortaya çıkararak teori ve öğretmen eğitimi literatürünü zenginleştirme potansiyeline sahiptir.

TPAB üzerine yapılan önceki araştırmalar genellikle müdahale çalışmaları (örneğin, Kafyulilo vd., 2015; Lyublinskaya ve Tournaki, 2014) veya tarama çalışmaları (örneğin, Kiray, 2016; Voogt vd., 2013) gibi nicel yaklaşımlar benimsemiştir. Mishra ve Koehler'in (2006) vurguladığı gibi, TPAB'ı niceliksel olarak ölçmek için öz değerlendirme anketleri yerine performansa dayalı değerlendirmeler yoluyla TPAB'ı değerlendirmek daha uygundur. Bu nedenle, bu çalışma hizmet içi öğretmenlerden veri toplamakta ve sonuçların uygunluğu, yargıların doğruluğu ve güvenilirliği konusunda daha sağlam kanıtlar sağlamak için bunları görüşmeler ve gözlemlerle üçgenlemektedir (Fisser vd., 2015; Mouza, 2016). Sonuç olarak bu yaklaşım, öğretmenlerin eylemlerine dayalı daha anlamlı veriler üreterek TPAB'ın doğasına ışık tutmaktadır. Mevcut literatürün, öğretme ve öğrenme sürecinde teknoloji entegrasyonunun karmaşık dinamiklerini ortaya koyan uygulamada TPAB'ı inceleyen daha fazla araştırma yapılması çağrısı (Yeh vd., 2014) göz önüne alındığında, bu çalışma bu boşluğun giderilmesine katkıda bulunmaktadır.

Önceki araştırmalar, TPAB kavramını çeşitli eğitim bağlamlarında keşfetmiş olsa da özellikle TPAB-P bileşenleri arasındaki etkileşimi ve uygulamadaki tezahürlerine ilişkin literatürde bir boşluk bulunmaktadır (Ay vd., 2015). Bu çalışma, fen bilimleri öğretmenlerinin TPAB-P'nin dinamik ve bağlamsal doğasını inceleyerek, onların BİT araçlarını fen öğretimleri sırasında nasıl pratik bir şekilde kullandıklarını araştırmayı amaçlamaktadır. TPAB-P bileşenleri arasındaki etkileşimleri, öğretmenlerin eylemleri ve kendi açıklamaları yoluyla araştırarak, bu çalışma, fen bilimleri öğretmenlerinin TPAB-P'nin boyutlarına değerli içgörüler sunmayı hedeflemektedir.

Diğer yandan, önceki çalışmalar, teknolojinin fen öğretimine entegrasyonunu çeşitli fen konularını kapsayarak incelemişlerdir. Örneğin, simülasyon ve animasyonların dahil edilmesinin öğrenci öğrenimi, başarı ve fen bilimlerine yönelik tutumları artırabileceğini gösteren araştırmalar bulunmaktadır (Adams, 2010; Jaakkola vd., 2011; Yildirim ve Sensoy, 2018). Bununla birlikte, kuvvet ve enerji konularının öğretimi, kavram yanlışları potansiyeli ve öğrencilerin kavramları ve teorileri anlamasındaki güçlükler gibi benzersiz zorluklar ortaya çıkarmaktadır (Megalakaki ve Thibaut, 2016; Sullivan vd., 2017). Bu nedenle, bu çalışmada konuya özgü bir TPAB yaklaşımı benimsendiğinden, ana odak noktası hizmet içi fen bilimleri öğretmenlerinin TPAB'ını kuvvet ve enerji merkezli bir yedinci sınıf öğrenme ünitesinde araştırmak olmuştur.

Sonuç olarak, bu çalışmanın önemi ele alınan araştırma sorularıyla sıkı bir şekilde bağlantılıdır. Bilimsel ve teknolojik alanlarda dünya hızla ilerledikçe, fen bilimleri öğretmenlerini değişen bir ortamın öncüsü olarak konumlandırmaktadır. Teknolojinin fen eğitime entegre edilmesi gerekliliği, öğrenci başarısı üzerindeki olumlu etkileriyle desteklenmektedir (Turan, 2023). Bu talepleri karşılamak için fen bilimleri öğretmenleri, sadece konu alan bilgisine dair derin bir bilgi sahibi olmakla kalmayıp aynı zamanda TPAB konusunda yeterlilik de sergilemelidir. Bu yeterlilik, sadece bir eğitim zorunluluğu olmakla kalmayıp aynı zamanda öğrencileri dijital çağa hazırlamak için de kilit bir faktördür. Bu nedenle, bu araştırma hizmet içi fen bilimleri öğretmenlerinin TPAB-P düzeylerini kuvvet ve enerji konularını öğretme bağlamında incelemeyi amaçlamaktadır. Aynı zamanda, TPAB-P bileşenleri arasındaki dinamik etkileşimlere odaklanarak bu bileşenlerin belirli fen konularının öğretimi sırasında nasıl ortaya çıktığına dair değerli içgörüler sunmaktadır.

2. Literatür Taraması

TPAB kavramsal çerçevesi, pedagojik bilgi (PA), konu alan bilgisi (AB) ve teknoloji bilgisi (TB) arasındaki karmaşık ilişkileri anlamak için temel bir yapıya sahiptir. Shulman'ın PAB'sından türemiş olan TPAB, eğitimde etkili teknoloji entegrasyonuna olan artan talebe yanıt olarak Mishra ve Koehler (2006) tarafından tanıtılmıştır. PB, öğretim ve öğrenme yöntemleri, teknikleri ve süreçlerini içerirken, AB konu içeriğine odaklanır. AB'nin teknolojilerle kesiştiği noktada TAB oluşur ve belirli teknolojiler

kullanılarak içeriğin dönüştürülmesini vurgular. Benzer şekilde, TPB, öğretimde kullanılmak üzere geliştirilen teknolojilerin bilgisini ve bu teknolojileri gerekli pedagojik bilgiyle kullanma bilgisini kapsar. TPAB, TPAB çerçevesinin merkezinde konumlanmış olup, PB, AB ve TB arasındaki dinamik ilişkiyi temsil eder ve öğretmenlerin etkili teknoloji öğretimi için bu etkileşimi yönlendirmeleri gerektiğini vurgular.

TPAB'a ilişkin bütünleştirici ve dönüştürücü olmak üzere iki görüş, TPAB'ın gelişimine ışık tutmaktadır. Bütünleştirici bakış açısı, özellikle PB, AB ve TB bileşenlerini artırmanın genel TPAB iyileştirmesine katkıda bulunduğunu ileri sürer. Buna karşılık, dönüştürücü bakış açısı, TPAB gelişiminin karmaşık bir süreç olduğunu, bireysel bilgi türleri yerine bütün yapıya yönelik açık bir eğitime ihtiyaç duyduğunu savunur. TPAB'ın epistemolojik doğası, Mishra ve Koehler'ın TPAB çerçevesi ve Angeli ve Valanides'in (2009) dönüştürücü TPAB-BİT modeli gibi görsel temsiller aracılığıyla tartışılmaktadır. TPAB'ın alan-genel mi yoksa alan-özgü mü olduğu sorusu, bağlam faktörleri ve farklı öğretim alanlarında TPAB'ın benzersiz özellikleri dikkate alınarak tartışılmaktadır.

Yeh vd. (2014) tarafından önerilen TPAB-P çerçevesi, TPAB'ın belirli içerik alanları içindeki birbirine bağlı doğasını vurgular. Dairesel bir çerçeve olarak görselleştirilen bu yapı, beş pedagojik alanı ve sekiz bilgi boyutunu içerir ve öğretimde BİT'lerin rolünü vurgular. Çerçevenin yineleyici doğası ve TPAB gelişiminde öğretim deneyiminin önemi vurgulanır. Değerlendirme, öğrenciler, konu içeriği, müfredat tasarımı ve pratik öğretim bilgisi gibi alanları kapsayan sekiz bilgi boyutunu içerir. BİT kullanma yetenekleri, çeşitli öğrenci özelliklerini anlama, teknolojiyi belirli konulara entegre etme ve BİT ile zenginleştirilmiş müfredat planlama konularında yeterlilikler vurgulanır. Çerçeve, öğretmen uygulama bilgisinin ve PAB'ın öğretim sürecini düzenlemedeki merkezi rolünü tanıır. Öğrenciler, pedagoji, temsil biçimleri ve araç avantajları gibi temel unsurlar, öğretmenlerin TPAB'ını şekillendirmede kritik öneme sahiptir.

TPAB üzerine yapılan geniş araştırma öncelikli olarak öğretmenler arasındaki yeterlilik seviyelerine odaklanmış çeşitli boyutları keşfetmektedir. TPAB değerlendirmesi, özellikle kendi kendine değerlendirme anketlerinin baskın araçlar

olduğu başlangıcından beri ilgi çeken bir alan olmuştur. Anket güvenilirliğiyle ilgili endişeler, performans temelli değerlendirmeler, görüşmeler ve gözlem raporları gibi alternatif araçların keşfedilmesine yol açmıştır. Nitel yöntemler, görüşmeler ve performans değerlendirmeleri de dahil olmak üzere, öğretmenlerin düşünce süreçleri hakkında değerli içgörüler sunar. Özellikle TPAB-P çerçevesi kullanılarak yapılan TPAB yeterlilik çalışmaları, öğretmenlerin gerçek öğretim uygulamalarındaki performanslarına dayanarak öğretmenlerin yetenek seviyelerini kategorize etmektedir. TPAB-P ötesinde, tasarım, çaba, etik ve yetenek gibi faktörlere ışık tutarak TPAB yeterliliğinin kapsamlı bir anlayışına katkıda bulunan diğer çerçeveler ve metodolojiler de bulunmaktadır. Bu çalışmalar, fen bilimleri öğretmenliği eğitim programlarının TPAB yeterliliğini geliştirmedeki önemini vurgular ve öğretmenler arasındaki dijital yetenekleri artırmak için sürekli profesyonel gelişim ihtiyacını ortaya koymaktadır.

TPAB bileşenleri arasındaki etkileşimin araştırılması, teknolojik, pedagojik ve alan bilgisi arasındaki dinamik ve evrilen bir ilişkiyi ortaya koymaktadır. Niess (2011), Pamuk vd. (2015) ve Schmidt vd. (2009) tarafından yapılan çalışmalar gibi bu çalışmalar, TPAB gelişimini belirli içerik bağlamlarında yönlendirme konusundaki zorluklara vurgu yapar ve ikinci seviye bilgi tabanlarının (TPB, TAB, PAB) önemli etkisini vurgular. Özgen ve Narlı (2020), Chen ve Hsu (2021) ve Murlam vd. (2021) gibi son dönem araştırmalar, COVID-19 pandemisi sırasında öğretmenlerin TPAB'ındaki değişikliklere işaret ederek TPAB dinamiklerini incelemektedir. Bulgular, bu ilişkilerin dinamik doğasını ve etkili teknoloji entegrasyonunu kolaylaştırmak için kapsamlı bir anlayışa duyulan ihtiyacı vurgulamaktadır.

3. Yöntem

Bu araştırma, yapılandırmacı bir yaklaşıma dayanmaktadır. Merriam ve Tisdell'in (2016) önerdiği yorumlu durum çalışması metodolojisiyle uyumludur. Ontolojik olarak yapılandırmacı bir bakış açısını benimser, yani tek bir gözlemlenebilir gerçeklik olmadığını ve gerçeğin sosyal bir ürün olduğunu vurgular. Epistemolojik olarak ise pragmatik bir yaklaşım benimser, yani evrensel yasalar arayışının ötesine geçer ve bağlam spesifik anlayışı vurgular. Bu felsefi yönelim, fen bilimleri öğretmenlerinin TPAB'ını okul bağlamında anlamayı ve araştırmanın derinliğini artırmayı

amaçlamaktadır. Yapılan araştırma tasarımı, öğretmenlerin deneyimlerini zengin ve kapsamlı bir şekilde betimlemeyi hedefler ve veri toplama ve analiz süreçlerini şeffaf ve tarafsız kılar. Sonuç olarak, yapılandırmacı ve pragmatik felsefi yaklaşım, araştırmanın derinliğini ve güvenilirliğini artırır.

3.1. Araştırma Deseni

Bu çalışma, fen bilimleri öğretmenlerinin TPAB-P'lerinin karmaşık yönleri keşfetmek için nitel bir araştırma metodolojisini benimsemektedir. Nitel bir tasarımın seçilmesinin temel nedeni, fen bilimleri öğretmenlerinin TPAB-P hakkında zengin ve detaylı bilgi toplama ihtiyacından kaynaklanmaktadır. Bu yaklaşım, fen bilimleri öğretmenlerinin TPAB-P seviyeleri hakkında sağlam kanılar ve içgörüler elde etmeyi mümkün kılmış ve TPAB-P bileşenlerinin birbirleriyle nasıl etkileşime girdiğini ortaya çıkarmıştır.

Bu çalışmada nitel durum çalışması yöntemi benimsenmiştir çünkü durum çalışmaları belirli bir konuya, belgeye, ortama veya olaya ayrıntılı bir inceleme yapmaya odaklanır. Durum çalışmaları, gerçek dünya ayarları içinde vakaları derinlemesine incelemek için ampirik bir yaklaşım sağlar. Bu yöntem, fen bilimleri öğretmenlerinin TPAB-P yeteneklerini ve TPAB-P bileşenlerinin etkileşimlerinin doğasını araştırdığı için bu amaç için uygun görülmüştür.

Bu çalışma, dört fen bilimleri öğretmenin TPAB-P yeteneklerini ve TPAB-P bileşenlerinin etkileşimlerinin doğasını kapsamlı bir şekilde incelemeyi hedeflediği için çoklu durum çalışması olarak tasarlanmıştır. Ayrıca, çalışma belirli yerler ve bir zaman dilimi ile sınırlandırılmıştır. Bu belirli sınırlar, 2021-2022 Güz döneminde Türkiye'nin Güneydoğu Anadolu Bölgesi'nin küçük bir ilinde bulunan bir kentsel devlet ortaokulundaki dört sınıf olarak tanımlanmıştır.

3.2. Katılımcı seçimi

Katılımcı seçimi için coğrafi faktörlere dayanan ve amaçlı örneklemeyi içeren bir süreç izlenmiştir. BİT ile zenginleştirilmiş öğretim yöntemlerini kullanan fen öğretmenleri, Türkiye'nin güneydoğusundaki bir ilde belirlenmiştir. Bu seçim sürecinde, öğretmenlerin BİT araçlarını sıkça kullanmaları ve yedinci sınıf kuvvet ve enerji konularını öğretmeleri gibi kriterler göz önünde bulundurulmuştur. Farklı

deneyim ve eğitim durumlarına sahip dört öğretmen ile araştırma hedeflerine daha derinlemesine ulaşmada yardımcı olacak şekilde tasarlanan çoklu durum çalışması tasarımına katkıda bulunmaktadır. Takma isimler verilen bu dört öğretmenin özellikleri kısaca şu şekildedir:

Asaf: 46 yaşındaki erkek bir öğretmendir ve 24 yıllık öğretmenlik deneyimine sahiptir. Kimya Eğitimi alanında lisans derecesine sahiptir ve BİT konusundaki yeteneklerini geliştirmek için çeşitli profesyonel gelişim kurslarına katılmıştır. Öğrencilerinin etkin katılımına olan bağlılığı, zengin ve kapsayıcı bir öğrenme deneyimi sunma arzusunu vurgulayan bir öğretmen profiline sahiptir.

Bora: 45 yaşındaki erkek bir öğretmendir ve 24 yıllık öğretmenlik deneyimine sahiptir. Kimya Eğitimi alanında lisans derecesine sahiptir ve BİT konusundaki profesyonel gelişim eğitimlerine ek olarak “formatör” olarak bilinen bir mentor öğretmen olarak görev yapmaktadır. BİT kullanımına yönelik pragmatik bir yaklaşım benimsemekte ve hazır eğitim içeriklerini kullanmayı daha çok tercih etmektedir.

Cenk: 31 yaşındaki erkek bir öğretmendir ve 7 yıllık öğretmenlik deneyimine sahiptir. Fen Bilgisi Eğitimi alanında lisans derecesine sahiptir ve BİT ile ilgili temel kursları almıştır. Derslerini düzenli bir yapı içinde sunma ve öğrencilerini aktif bir şekilde teknoloji destekli öğrenme deneyimlerine dahil etme amacını taşımaktadır.

Esin: 29 yaşındaki bir kadın öğretmendir ve 5 yıllık öğretmenlik deneyimine sahiptir. Fen Bilgisi Eğitimi alanında lisans ve yüksek lisans derecelerine sahiptir. BİT konusundaki eğitimini lisans ve lisansüstü çalışmaları sırasında aldığı derslerle desteklemiştir. Güvenli ve sorumlu BİT kullanımını teşvik etme amacı, Esin’in öğretim yaklaşımında belirgin bir özelliktir.

3.3. Veri toplama araçları

Bu çalışmada, TPAB’ın doğasını anlama ve TPAB yeterliliğini değerlendirme amaçlarına tek bir veri kaynağıyla ulaşmak zor olduğundan farklı veri toplama araçları kullanılmıştır. Çalışma ile ilgili araştırma sorularıyla ilgili katılımcılardan bilgi toplamak için çeşitli veri toplama araçları kullanılmıştır çünkü çoklu veri toplama araçları, hizmet içi fen öğretmenlerinin TPAB’ını ayrıntılı bir şekilde değerlendirmeye ve keşfetmeye olanak tanımıştır. Bu çalışmada kullanılan araçlar arasında görüşmeler

ve ders içi gözlemler bulunmakta olup veri toplama süreci dokuz hafta boyunca sürmüştür.

Görüşmeler: Öğretmenlerin BİT araçlarının fen öğretimlerine nasıl entegre ettikleri konusunda derinlemesine bilgi sağlamak amacıyla öğretim uygulamalarından sonra yapılmıştır. Yarı yapılandırılmış bir görüşme protokolü, hizmet içi fen öğretmenlerinin TPAB'ını çıkarmak için 18 ana soruyu içerecek şekilde hazırlanmıştır. Görüşme soruları, öğretmenlerin neden ve nasıl BİT araçlarını kullandığını sorgulamanın yanı sıra, öğrencileri anlama ve değerlendirme, planlama ve tasarlama ile öğretim uygulamaları boyutlarında yeterlilik düzeylerini keşfetmek için tasarlanmıştır.

Gözlemler: Öğretmenlerin BİT araçlarını kullanma biçimlerini, öğrencileri anlama ve değerlendirme, planlama ve tasarlama, ve öğretimde uygulama süreçlerini kaydetmeyi amaçlayarak yapılmıştır. Gözlem protokolü, gözlemler sırasında kaydedilmesi gereken ana unsurları belirlemiş ve bu gözlemlerin TPAB-P çerçevesinin beş bileşeni üzerinde odaklanmasına rehberlik etmiştir.

3.4. Veri analizi

Merriam ve Tisdell'a (2016) göre, veri analizi toplanan veriyi düzenleme ve yönetme sürecini içeren sistemli bir süreci içermelidir ki bu transkript edilmiş görüşmeler, gözlemler ve diğer veri kaynaklarını içerir. Nitel araştırmalarda tek bir standart veri analizi yöntemi olmasa da Creswell (2009), veri analiz sürecini raporlamak için birkaç adım belirler. Bu süreç, tüm sesli kayıtların (görüşme verileri) ve video kayıtların yanı sıra gözlem notlarının (gözlem verileri) araştırmacı tarafından elektronik formata aktarılmasıyla başlamıştır. İkinci adım, tüm veriye hâkim olmak için tüm veriyi dikkatlice okuma ve tekrar okumayı içerir. Üçüncü adım kodlama sürecidir. Bu aşamada, transkripte edilmiş veriler, kelime, tamlama, cümle veya paragraflar şeklinde veri noktalarına bölünmüş ve kodlar olarak tanımlanmıştır. Bu çalışmada, tümdengelimsel içerik analizi ve birleşik yaklaşımı içeren bir kodlama süreci kullanmıştır. Dördüncü adım, analiz için desenler veya temalar oluşturmaktır. İlk amaç için, katılımcıların yeterlilik düzeylerini değerlendirmek anlamına gelirken, ikinci amaç için TPAB bileşenleri arasındaki olası etkileşimleri belirlemeyi gerektirmiştir. Bulgular, her öğretmen için TPAB haritaları oluşturmak için kullanılmıştır. Veri analizinin beşinci adımında, bulguları iletmek için anlatı pasajları kullanıldı. Bu

anlatılar, öğretmenlerin ifadelerinden doğrudan alıntılardan ve gözlem segmentlerinin yazılı açıklamalarından oluşmaktadır. Veri analizinin son adımında, araştırmacı, ilgili teorik çerçeve ve perspektiflerin desteğiyle bulguları yorumlamıştır. Bu adım, bulguların benzerliklerini ve farklılıklarını tartışmayı, önceki araştırma bulgularıyla karşılaştırmayı ve nihayetinde çalışmadan anlamlı sonuçlar çıkarmayı kolaylaştırmıştır.

TBAB Yeterlilik Düzeyleri İçin Veri Analizi: Çalışmadaki ilk araştırma sorusunun analizi ile, hizmet içi fen öğretmenlerinin TPAB yeterlilik düzeyleri, görüşmelerden ve öğretim gözlemlerinden elde edilen verilere dayanarak incelenmiştir. TPAB-P yeterlilik düzeylerinin değerlendirilmesinde Yeh ve meslektaşlarının (2015b) geliştirdiği bir rubrik kullanılmıştır. Bu rubrik, değerlendirme, planlama ve tasarlama ve öğretim uygulamaları olmak üzere üç genel kategorideki kriterleri içermektedir. Bu kriterler, katılımcıların yeterlilik düzeylerini belirlemede katkıda bulunmuştur.

TBAB Bileşenleri Arasındaki Etkileşimlerin Analizi: Çalışmanın ikinci araştırma sorusu, TPAB-P bileşenleri arasındaki etkileşimin keşfi ile ilgilidir ve bu etkileşimleri inceleyerek ele alınmıştır. TPAB bölümleri belirlendikten sonra araştırmacı, TPAB-P bileşenleri arasındaki etkileşimlerin doğasını analiz etmek için Park ve Chen (2012) tarafından PAB'ın beşgen modeli üzerine yapılan çalışmada kullanılan benzer bir yaklaşım benimsemiştir. Sonuç olarak, üç aşamalı bir veri analizi prosedürü izlendi. Bu adımlar, derinlemesine doğrudan TPAB analizi, numaralandırma yaklaşımı ve sürekli karşılaştırmalı yöntemi içermektedir.

Derinlemesine Doğrudan TPAB Analizi: Katılımcıların TPAB'ına özgü öğretim segmentlerinde entegre edilen bileşenleri belirlemeyi amaçlamaktadır. Bu öğretim segmentleri, TPAB-P çerçevesinden en az iki TPAB bileşeninin entegre olduğu durumlar olarak tanımlanmıştır. Bu segmentlere TPAB bölümleri denir ve TPAB-P çerçevesi içinde BİT araçlarının veya BİT tabanlı öğretim süreçlerinin kullanımına dair kanıt sağlar. Örneğin, öğrencilerin Dünya'nın yerçekimi kavramını resimler veya sözlü açıklamalardan anlamakta zorlandığı durumlarda bir öğretmen, öğrencilere akıllı tahtada bir animasyon kullanmaya karar verebilir. Bu, Öğrenen Bilgisi ile Öğretim Programı Tasarımı Bilgisi arasında tek yönlü bir etkileşimi gösterir.

Numaralandırma Yaklaşımı: TPAB bileşenleri arasındaki etkileşimler, analitik bir araç

olarak TPAB-P modeli kullanılarak gösterilmiş ve bunun bir TPAB-P haritası olarak tanımlanmıştır. Her TPAB-P haritası, haritada yer alan bileşenler arasında en az bir bağlantı olduğunu varsayar ve harita üzerindeki bileşenler arasında “1” gücünde bağlantılarla temsil edilmiştir.

Sürekli Karşılaştırmalı Yöntem: Bu yaklaşım önceden belirlenmiş kategorilere veya çerçevelere dayanmaksızın TPAB bileşenleri arasında ortak desenlerin ve düzenliliklerin keşfini kolaylaştırmış, bu da indüktif ve karşılaştırmalı bir veri analizi süreci haline getirmiştir. Bu yöntemde, TPAB-P haritaları ve ilgili TPAB bölümleri birbirleriyle karşılaştırılarak benzerlikler ve farklılıklar belirlenmiş ve bu bölümlerin kategorize edilmesine olanak tanımıştır. Bu süreç, bu çalışmanın ikinci hedefi olan hizmet içi fen öğretmenlerinin TPAB’ları hakkında bazı savların ortaya atılmasına olanak sağlamıştır.

3.5. İnandırıcılık

Yapılandırmacı nitel araştırmada güvenilirliği sağlamak için etik konulara dikkat etmenin yanı sıra ele alınması gereken bazı hususlar vardır. Merriam ve Tisdell (2016), Lincoln ve Guba (1985) tarafından ortaya konan terminolojiye dayanarak bunları iç geçerlilik için ‘inanılrlık’, güvenilirlik için ‘tutarlılık’ ve dış geçerlilik için ‘aktarılablrlık’ olarak adlandırmıştır.

İnanılrlık: Araştırmanın inanılrlığı, elde edilen bulguların gerçekte ne kadar uyumlu olduğu ve sonuçların gerçeklere ne kadar yakın olduğu sorularına odaklanır. Nitel araştırmalarda, bu inanılrlığı artırmak için veri üçgenleme, üye kontrolü, yeterli zaman harcama, araştırmacı yansıtıcılığı, akran bilgilendirmesi ve geri çeviri gibi çeşitli teknikler kullanılmıştır.

Tutarlılık: Nitel araştırmada, tutarlılık için temel odak noktası elde edilen sonuçların toplanan verilerle uyumlu olup olmadığıdır. Bu hedefe ulaşmak için veri üçgenleme, akran bilgilendirmesi, araştırmacı yansıtıcılığı ve denetim izi gibi stratejiler kullanılmıştır. Denetim izi açısından, bu çalışma boyunca şeffaflığı ve güvenilirliği artırmak amacıyla yoğun bir belgeleme süreci izlenmiştir. Bu kapsamlı belgeleme yöntem bölümünde detaylı bir açıklama ile başlamış olup, çalışmanın tasarımını, katılımcı seçim kriterlerini ve veri toplama araçlarının kapsamlı açıklamalarını

içermektedir.

Aktarılabilirlik: Nitel bir çalışmanın sonuçlarının başka bir bağlama aktarılabilirliğini ifade eder. Bu konuda katılımcı seçimi ve bulguların detaylı açıklamaları, çalışmanın sonuçlarını benzer bağlamlar veya durumlarla anlamlandırmada okuyuculara yardımcı olabilir. Bulguların aktarılabilirliğini desteklemek için ayrıca zengin ve detaylı açıklamalar sunulmuştur. Böylece okuyucular bulguların benzer bağlamlar veya durumlarla ne kadar ilgili ve uygulanabilir olduğunu değerlendirebilir.

Bu çalışmada, Merriam ve Tisdell'e (2016) göre nitel araştırmalardaki etik düşünceler, araştırmacının güvenilirliğini sağlamak için ayrılmaz bir öneme sahiptir. Araştırmacı, veri toplamadan bulguların raporlanmasına kadar olan süreçte güvenilirlik, entelektüel titizlik ve etik yeterliliği göstermek için kararlı davranmıştır. İlk olarak, pilot çalışma ve ana çalışma için gerekli izinler alınmış ve etik onaylar sağlanmıştır. Katılımcı seçimi sırasında gizliliği vurgulamak amacıyla öğretmenlere takma adlar atanmış ve video kayıtları güvenli bir şekilde saklanmıştır. Araştırmacı, veri analizi aşamasında kişisel yorumlardan kaçınarak objektif bir yaklaşım benimsemeye çalışmış ve güvenilirliği artırmak için kodlayıcılar arası fikir birliği aramıştır. Bu etik yaklaşım, araştırmacının çalışmayı dürüstlük ilkesiyle yürütmeye olan bağlılığını yansıtmaktadır.

4. Bulgular

TPAB-P çerçevesi, yeterlilik düzeylerini değerlendirmek için değerlendirme, planlama ve tasarlama ve öğretim uygulamaları olmak üzere üç eğitim boyutunu kapsadığından, öğretmenlerin yeterlilik düzeyleri buna göre raporlanmıştır. Her öğretmen için yeterlilik düzeyleri rubrikte yer alan şu yeterlik düzeylerine göre sınıflandırılmıştır: kullanım eksikliği, basit benimseme, kaynaştırıcı uygulamalar ve yansıtıcı uygulamalar. Öğretmenlerin TPAB-P yeterlilik düzeyleri değerlendirme boyutunda analiz edildiğinde, yeterliliklerinde kayda değer bir farklılaşma ortaya çıkmaktadır. Örneğin, Asaf, Bora ve Cenk, kavram yanlışlarını tespit etmek için BİT araçlarının faydasına aşina olduklarını gösteren basit benimseme seviyesiyle uyumlu bir yeterlilik gösterirken, bu araçları öğrencilerin öğrenme ihtiyaçlarını değerlendirmek için kullanmaları sınırlı kalmaktadır. Buna karşın Esin, yansıtıcı uygulamalar olarak kategorize edilen oldukça yüksek bir yeterlilik seviyesiyle öne

çıkmaktadır.

Diğer taraftan, planlama ve tasarlama boyutunda TPAB-P yeterlilik seviyeleri incelendiğinde, yeterliliklerin çeşitliliği görülmektedir. Örneğin Asaf, sınıf içinde görselleştirmeyi ve motivasyonu artırmak için temsilleri kullanmaya odaklanarak sürekli olarak basit benimseme düzeyinde yer almaktadır. Bununla birlikte, öğretim yaklaşımı daha çok öğretmen merkezli yöntemlere yönelme eğilimindedir. Bu durum, BİT dışı hedef belirlemeyi vurgulayan ve tamamen öğretmen merkezli öğretime meyilli olan Bora'nın kullanım eksikliği kategorisine girmesiyle tezat oluşturmaktadır. Buna karşılık Cenk, öğretmen merkezli bir yaklaşımı sürdürürken içerik ve görselleştirmeyi geliştirmek için BİT araçlarını etkili bir şekilde dahil ederek, kaynaştırıcı uygulamalar yeterliliğini sergilemektedir. Benzer şekilde, Esin'in planlama ve tasarlama boyutundaki yeterlilik düzeyi de kaynaştırıcı uygulamalar olarak değerlendirilmiştir.

Öğretmenlerin TPAB-P yeterlilik düzeylerinin öğretim uygulamaları boyutunda analizi bir yeterlilik yelpazesi ortaya koymuştur. Asaf ve Bora, BİT araçlarının öğretim üzerindeki olumlu etkisini anladıklarını gösteren, BİT'leri öğretim bağlamlarına dahil etme açısından basit benimseme düzeyiyle uyumlu bir yeterlilik sergilerken, Cenk ve Esin kaynaştırıcı uygulama yeterlilik düzeyiyle öne çıkmaktadır. Cenk, görsel olarak çekici ve etkileşimli BİT araçlarının entegrasyonu yoluyla genel öğretim deneyimini etkili bir şekilde geliştirmekte, öğretim için BİT entegrasyonunda öncelikle kolaylık ve geliştirmeyi vurgulamaktadır. Esin'in yeterlilik seviyesi, öğrencilerin ilgisini çekmek ve öğrenme deneyimlerini geliştirmek için BİT araçlarının etkili kullanımına ilişkin ileri düzey anlayışını vurgulayarak kaynaştırıcı uygulama ile uyumludur.

Beş TPAB-P bileşeni arasındaki etkileşimlerin doğasını anlamak için yapılan analizlerin sonucunda birtakım benzerlikler ve farklılıklar tespit edilmiştir. Örneğin, TPAB-P haritalarının genel yapıları, bileşenlerin benzer bir düzenini ya da tertibini paylaşmamaktadır. Örneğin, Asaf'ın haritasında bileşenler, BİT rehberliği, teknoloji ve sınıf yönetiminin öğretimindeki merkezi rolünü vurgulayacak şekilde düzenlenmiştir. Buna karşın, Esin'in haritası teknoloji temelli fen öğretiminde planlama ve tasarımın önemini vurgulayan farklı bir düzen sergilemektedir. Genel yapıdaki bu farklılıklar, her öğretmenin TPAB-P haritasını kendine özgü öğretim

bağlamına göre şekillendirdiğini göstermektedir. Sonuç olarak, Asaf, Bora, Cenk ve Esin'in TPAB-P haritalarının kapsamlı bir analizi yapılmış, teknolojinin öğretim uygulamalarına entegrasyonuna yönelik yaklaşımlarındaki farklı özellikler ve ortak noktalar tespit edilmiştir. Bulgular, TPAB'ın karmaşık doğasına ışık tutan birkaç temel sav ortaya koymuştur. Temel olarak bu iddialar kabaca değerlendirmenin öğretim uygulamalarındaki etkili rolü, her öğretmenin TPAB-P haritasının benzersizliği, değerlendirme odaklı teknoloji entegrasyonu eğilimi, konu içeriği sunumunun yeterince kullanılmayan potansiyeli ve dinamik TPAB-P doğası olarak özetlenebilir.

5. Tartışma, Sonuç ve Öneriler

5.1. Fen Bilimleri Öğretmenlerinin TPAB-P Yeterlik Düzeyleri

Genellikle kabul görenin aksine bu çalışma, daha yüksek öğretim deneyiminin doğrudan daha yüksek TPAB-P yeterlilik seviyelerine yol açtığı düşüncesini sorgulamaktadır. Esin ve Cenk gibi daha az deneyime sahip öğretmenlerin sergilediği örnek uygulamalar, inovasyon ve uyum sağlama yeteneklerinin sıklıkla profesyonelliğe daha yeni adım atmış bireylerde gelişebileceğini göstermiştir. Değerlendirme boyutuyla ilgili olarak, sınıfta yapılan değerlendirmelerde temel BİT araçlarının yaygın olarak kullanıldığını gözlemlenmiştir. Zaman kısıtlamaları ve sınav odaklı uygulamalar, profesyonel gelişimde incelikli stratejilere olan ihtiyacı vurgulayarak önemli etmenler olarak ortaya çıktığı düşünülmektedir. Planlama ve tasarlama boyutuna geçildiğinde bulgular, öğretmenler arasında çeşitli yetenek seviyelerini sergileyen bir yelpazenin var olduğunu göstermiştir. Bu farklı yeterlik düzeylerinin oluşmasında planlama yaklaşımlarındaki çeşitlilik, deneyim, teknoloji bilgisi ve bağlamsal kısıtlamalar gibi faktörlerin rol oynadığı düşünülmektedir. Uygulama boyutunda ise dersler sırasında teknik zorluklarla karşılaşmanın yaygın bir durum olduğunu gözlemlenmiştir. Bu bağlamda, şaşırtıcı bir şekilde yalnızca teknoloji okuryazarlığı seviyesinin kendi başına yeterli olmadığı, başarılı teknoloji entegrasyonu için yedek planlara sahip olmanın kritik bir unsur olarak ortaya çıktığı görülmüştür.

5.2. TPAB-P Bileşenleri Arasındaki Etkileşimlerin Doğası

KoPiT ve KoA arasındaki güçlü etkileşimlerin yaygınlığı, değerlendirmenin öğretim

uygulamalarını etkilemedeki kritik öneminin altını çizmektedir: Toplanan verilere ve hizmet içi fen öğretmenlerinin TPAB-P haritalarına dayanarak, her bir öğretmende en yüksek etkileşimlerin Öğretim Uygulamaları Bilgisi (KoPiT) ve Değerlendirme Bilgisi (KoA) arasında gerçekleştiği görülmüştür. Bu etkileşimler, öğretmenlerin BİT zorluklarına çözüm bulma, öğrenci ihtiyaçlarına uygun öğretim yönetimi ve öğrencilere teknoloji kullanımında rehberlik etme becerilerini içermektedir. Bu durum, öğretmenlerin teknolojik yeterlilik, öğretim yönetimi ve öğrenci rehberliği arasındaki kritik bağlantıyı vurgulamaktadır.

KoPiT ve KoA arasındaki etkileşimler, öğretmenlerin BİT ile ilgili zorlukları ele almak, öğretim yönetimini öğrenci ihtiyaçlarına uyarlamak ve öğrencilere bilimsel değerlendirmeler için etkili bir şekilde teknolojiyi kullanma stratejilerini gösterir. Bu etkileşim, özellikle Asaf'ın sınıf içi formatif değerlendirmeleri ve Cenk'in sınıf dışı formatif değerlendirmeleri için dijital platformları başarılı bir şekilde kullanma örneklerinde belirginleşmiştir. Bu sonuçlar, öğretmenlerin bilim eğitiminde etkili teknoloji entegrasyonunu teşvik etmeye yönelik TPAB-BİT etkileşimlerinin önemini vurgulamaktadır. Ayrıca, bu etkileşimin sınıf içi ve dışı değerlendirmelerde kullanımının öğrencilere dijital beceriler kazandırmada önemli bir rol oynadığını göstermektedir. Bu bulgular, değerlendirmenin öğretim uygulamalarını şekillendirme ve öğrencileri dijital çağın gereksinimlerine hazırlama sürecindeki kilit rolünü vurgulamaktadır.

Sonuç olarak, belirlenen bu etkileşimlerin yaygınlığı, değerlendirmenin öğretim uygulamalarını şekillendirme ve öğrencileri 21. yüzyılın dijital ortamına hazırlama konusundaki önemini bir kez daha vurgulamaktadır.

Her öğretmenin TPAB-P haritasının kendine özgü düzeni, TPAB'ın benzersiz doğasını vurgulamakta ve iki öğretmenin aynı bileşen düzenlemesine sahip olmadığını vurgulamaktadır: Her öğretmenin TPAB-B haritasının kendine özgü düzeni, bileşenlerin kişiye özel düzenini vurgulayarak TPAB'ın benzersiz doğasının altını çizmektedir. İki öğretmen aynı yapıyı paylaşmaz; bu durum, TPAB haritalarının incelenmesinde, etkileşimlerin ve tercihlerin fen öğretiminde teknoloji entegrasyonunu şekillendirdiğini göstermektedir. Köşeleri birbirine bağlayan

izgilerin kalınlığı, etkileşimlerin sıklığını simgelemektedir ve bireysel TPAB çerçevelerinde belirli etkileşimlere dair içgörüler sunmaktadır. Çalışma, TPAB'nin benzersiz özelliklerini PAB'ın kendine özgü doğasıyla uyumlu hale getirir ve öğretmen bilgisinin karmaşık dinamiklerine dair etkili bir bilim öğretimi ve öğrenimi için teknoloji uygulama konusunda içgörüler sunmaktadır.

Tüm öğretmenlerin TPAB-P haritalarında değerlendirmeye yapılan tutarlı vurgu, değerlendirme odaklı teknoloji entegrasyonuna yönelik kapsayıcı bir eğilime işaret etmektedir: Öğretmenler arasında dikkat çeken bir eğilim, değerlendirme odaklı teknoloji entegrasyonuna olan genel yönelimin var olmasıdır. Özellikle formatif değerlendirme pratiğine odaklanarak, öğrenci anlayışlarını değerlendirmek için dijital kaynakları yoğun bir şekilde kullandıkları görülmüştür. Bu eğilim, öğrencilerin bilgiyi değerlendirmek ve anlamak için teknolojiyi kullanma eğilimini vurgulamaktadır. Öğretmenler, çeşitli BİT araçları ve çevrimiçi ödevler aracılığıyla biçimlendirici değerlendirmelere özel bir vurgu yapmışlar; eğitsel oyunlar gibi yenilikçi öğretim yöntemlerinin kullanımı, öğrenci katılımını artırma ve öğrenme deneyimini zenginleştirme amacını taşımışlardır. Bu bulgular, değerlendirme odaklı teknoloji entegrasyonunun fen öğretiminde yaygın bir eğilim olduğunu göstermiştir.

Öğretmenlerin TPAB-P haritalarında Konu Alan Bilgisi (KoSC) içeren sınırlı etkileşimler, BİT ile konu içeriği sunumunu geliştirmek için yeterince kullanılmayan bir potansiyele işaret etmektedir: Etkileşimlerin sınırlı olması, öğretmenlerin muhtemelen BİT'i anlama düzeyini artırmayı veya içerik iletimi için uygun BİT araçlarını bilinçli olarak seçmeyi önceliklendirmeyebileceğini göstermiştir. BİT'e olan değişen rahatlık düzeyleri, geleneksel yöntemlere bağlılık ve standartlaştırılmış sınav kısıtlamaları, bu entegrasyonun eksikliğine katkıda bulunduğu düşünülmektedir.

TPAB'ın dinamik doğası, öğretmenlerin TPAB-P haritalarında gözlemlenen farklılıklarda kendini göstermekte ve bu çerçevenin bireysel öğretim bağlamlarına ve tercihlerine uyum sağlama konusundaki uyarlanabilirliğini yansıtmaktadır: TPAB-P çerçevesi, öğretmenlerin TPAB-P haritalarındaki farklılıklarla gösterdiği dinamik bir yapı sergilemiştir. Bu, çeşitli öğretim bağlamlarına ve bireysel tercihlere uyum sağlama yeteneğini gösterir. TPAB'ın gücü öğretmenlere benzersiz öğretim durumlarına dayalı olarak entegrasyonu özelleştirme imkanı tanıyan içsel esnekliğinde

yattığı anlaşılmaktadır. Öğretmen etkenliği ile TPAB arasındaki simbiyotik bağlantıyı vurgulamak öğretmenlerin teknoloji entegrasyonunu şekillendirmedeki kilit rolünü ortaya koyduğu düşünülmektedir.

5.3. TPAB-P yeterliliği ile TPAB-P bileşenleri arasındaki etkileşimler arasındaki ilişkiyi kurmak

Öğretmenlerin yüksek TPAB-P yeterliliği her zaman daha entegre bir TPAB-P'yi işaret etmeyebilir. Bu durum geleneksel varsayımları sorgulamakta ve yeterlilik ile TPAB haritasının entegrasyonu arasındaki ilişkiyi daha yakından incelemeye teşvik etmektedir. Ayrıca, yeterlilik düzeylerinin tüm etkileşimlere eşit şekilde etki etmediği gözlemlenmiştir. Tam aksine bazı boyutlar yeterlilikteki ilerlemelere diğerlerinden daha fazla tepki verdiği gözlemlenmiştir. Yeterliliğin etkisi özeldir ve bireyseldir, bu da tek tip bir etki düşüncesine meydan okumakta ve yeterliliğin TPAB-P'nin farklı bileşenleri ile nasıl etkileşime girdiğinin anlaşılmasına ihtiyaç doğurmaktadır. Ayrıca, çalışma etkileşimlerin kalitesini vurgulayarak, yüksek yeterliliğin teknolojinin pedagojik uygulamalara daha stratejik ve amaçlı bir şekilde entegrasyonuna katkıda bulunduğunu, TPAB-P etkileşimlerinin nitel yönlerini şekillendirdiğini göstermektedir. Bu çalışmada gözlemlenen nüanslı ve stratejik entegrasyon, fen öğretimi içinde öğretim stratejilerini şekillendirmede TPAB-P yeterliliğinin dinamik doğasını vurgulayarak etkili öğretim uygulamalarıyla ilgili devam eden tartışmalara katkı sağlamaktadır.

5.4. Sonuç ve Öneriler

Bu araştırma, fen bilimleri öğretmenleri, politika yapımcıları ve program geliştiricileri ile fen öğretimi araştırmacıları için çeşitli sonuçlar taşıyor.

Fen Bilimleri Öğretmenleri İçin Sonuçlar: Çalışmanın bulguları teknoloji entegrasyonu konusundaki yeterlilik seviyelerinin artırılmasına dair önemli sonuçlar içermektedir. Mesleki gelişim atölyelerine katılımın, TPAB-P yeterliliğini artırma ve teknolojiyi fen öğretimine entegre etme becerilerini geliştirme konusunda hayati olduğu vurgulanmaktadır. Ayrıca, fen bilimleri öğretmenlerinin çevrimiçi platformlar aracılığıyla işbirlikçi öğrenme ortamları oluşturarak öğrencilere dijital beceriler kazandırmaları ve teknolojiyi etkili bir şekilde kullanmaları için teşvik edilmeleri

önerilmektedir.

Politika Yapıcıları ve Program Geliştiriciler İçin Sonuçlar: Fen bilimleri öğretmen eğitimi programlarının şekillendirilmesinde TPAB-P yeterlilik seviyelerinin kritik öneme sahip olduğu belirtilmiştir. Bu bulgulara dayanarak öğretmenlere yönelik hedefli profesyonel gelişim programları tasarlama ve uygulama ihtiyacı vurgulanmıştır. Ayrıca, teknolojinin fen öğretimi için nasıl etkili bir şekilde kullanılacağına dair politika ve stratejilerin oluşturulması önerilmektedir.

Fen Öğretimi Araştırmacıları İçin Sonuçlar: Fen bilimleri öğretmenlerinin TPAB-P yeterlilik seviyelerinin daha ayrıntılı bir şekilde incelenmesi, öğretmenler arasındaki farklılıkları anlama ve gelecekteki çalışmaları bilgilendirme potansiyeline sahiptir. Bulgular, önceki varsayımları sorgulayarak öğretmenler arasında yüksek yeterlilik seviyeleri ile TPAB bileşenleri arasında güçlü bir ilişki olduğu düşüncesine meydan okumuş ve hedefli profesyonel gelişim programlarının geliştirilmesine yönelik bir temel sunmuştur.

Bu çalışmanın bulguları ve tartışmaları ışığında aşağıdaki öneriler, fen bilimleri öğretmenlerine pratik rehberlik sunmak, bilinçli politika kararlarına ve program geliştirmeye katkıda bulunmak ve gelecekteki araştırma girişimlerine rehberlik etmek amacıyla sunulmuştur:

- Fen bilimleri öğretmenleri özellikle teknoloji entegrasyonundaki zorlukları ele alan ve içerik ile BİT araçlarının stratejik kullanımına odaklanan atölyelere öncelik vermeye teşvik edilmektedir.
- Öğretmenlere, eğitici oyunlar, etkileşimli unsurlar ve gelişmiş dijital araçları biçimlendirici ve sonuca dayalı değerlendirmelerde kullanarak değerlendirme stratejilerini çeşitlendirmeleri önerilmektedir.
- Fen bilimleri öğretmenleri çevrimiçi platformlar aracılığıyla işbirlikçi öğrenme ortamları oluşturarak öğrencilere dijital beceriler kazandırmaya ve teknoloji zengini bir eğitim ortamında etkin katılımı özendirmeye teşvik edilmektedir.
- Politika yapıcılar teknolojinin çeşitli entegrasyon biçimlerine uyum sağlayan esnek değerlendirme politikalarını geliştirmeyi düşünmelidir, böylece öğretmenlerin

yenilikçi değerlendirme stratejilerini benimsemelerine olanak sağlanabilir.

- Politika yapıcılarının, TPAB-P'nin öğrenci çıktıları üzerindeki etkisine ilişkin kanıta dayalı politikalar geliştirmeleri, teknolojinin kuvvet ve enerji konularında fen eğitimine entegre edilmesine yönelik stratejilerin araştırma bulguları tarafından desteklenmesini sağlamaları önerilmektedir.
- Araştırmacılara, TPAB-P yeterliliğinin nitel analizlerini daha fazla yapmaları, yeterlilik seviyeleri ile TPAB-B bileşenlerinin nitel yönleri arasındaki karmaşık bağlantıları ortaya çıkarmaları önerilmektedir.
- Araştırmacılar, öğretmenlerin TPAB yeterliliğinin öğrenci öğrenme sonuçları ve teknoloji entegre edilmiş fen sınıflarındaki katılım üzerindeki doğrudan etkisini keşfetmelidir.
- Farklı eğitim ortamlarında TPAB-P gelişimini etkileyen bağlamsal faktörlerin araştırılması, fen bilimleri öğretmenlerinin özel ihtiyaçlarına dayalı müdahalelerin özelleştirilmesine rehberlik etmesi açısından tavsiye edilmektedir.
- Öğretmenler TPAB yeterliliğine odaklanan mesleki gelişim girişimlerinden elde edilen içgörülerini birleştirerek, özellikle kuvvet ve enerji konularıyla ilgili ders planlarını aktif bir şekilde gözden geçirmeye ve yeniden tasarlamaya teşvik edilmektedir.
- Politika yapıcılar, teknolojinin müfredata dahil edilmesi için daha uyarlanabilir ve duyarlı bir yaklaşımı kolaylaştıran bir uygulamayı eski haline getirerek, öğretmenlerin günlük ders planları oluşturma gerekliliğini yeniden değerlendirmeye teşvik edilmektedir.
- Kuvvet ve enerji konularında belirlenen TPAB-P bileşenlerinin sınırlı etkileşimlerini geliştirmek için, özel mesleki gelişim programları TPAB-P arasındaki uyumlu bağlantıları teşvik ederek entegre uygulama stratejilerini vurgulamalıdır.

K. 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 : Uçar
Adı / Name : Murat Berat
Bölümü / Department : İlköğretim / Elementary Education

TEZİN ADI / TITLE OF THE THESIS (İngilizce / English): Exploring In-Service Science Teachers' Proficiency Levels and Nature of Interactions among Components of Technological Pedagogical and Content Knowledge-Practical

TEZİN TÜRÜ / DEGREE: Yüksek Lisans / Master ☐ Doktora / PhD ☒

- 1. TEZİN TAMAMI DÜNYA ÇAPINDA ERIŞİME AÇILACAKTIR. / RELEASE THE ENTIRE WORK IMMEDIATELY FOR ACCESS WORLDWIDE.** ☐
- 2. TEZ İKİ YIL SÜREYLE ERIŞİME KAPALI OLACAKTIR. / SECURE THE ENTIRE WORK FOR PATENT AND/OR PROPRIETARY PURPOSES FOR A PERIOD OF TWO YEARS. *** ☐
- 3. TEZ ALTI AY SÜREYLE ERIŞİME KAPALI OLACAKTIR. / 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

*(Kütüphaneye teslim ettiğiniz tarih. Elle doldurulacaktır.)
(Library submission date. Please fill out by hand.)*

Tezin son sayfasıdır. / This is the last page of the thesis/dissertation.