

DESIGNING A LEARNING ENVIRONMENT:
EMPOWERING PRESERVICE SCIENCE TEACHERS TO USE EVIDENCE
IN TEACHING PRACTICES



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ABSTRACT

Designing a Learning Environment:

Empowering Preservice Science Teachers to Use Evidence in Teaching Practices

Scientific evidence is a crucial component of scientific practices in developing scientific knowledge. However, preservice science teachers (PSTs) face challenges in incorporating evidence into their lessons. This study aimed to enhance PSTs' conceptual understanding of scientific evidence and enrich their teaching practices by incorporating evidence-based explanations. Design-based research was used to create a learning environment for PSTs within the context of a practicum course in a public university science education program. The learning environment was designed based on three principles derived from sociocultural learning theory, teacher learning research, and science education literature—providing scaffolding, facilitating reflection, and situating learning experiences in meaningful contexts. A pilot study and two cycles of implementation and refinement were conducted. Qualitative data were collected through questionnaires, interviews, observations of teaching practices, and lesson plans created by PSTs. The findings showed improvements in PSTs' conceptual understanding of evidence and the progression of their teaching practices toward evidence-based lessons. The results highlight the role of the three design principles in supporting their learning. The current research offers valuable insights for enhancing science teacher education, demonstrating how well-designed learning environments can equip PSTs with the essential pedagogical content knowledge needed for teaching evidence-based lessons.

ÖZET

Bir Öğrenme Ortamı Tasarımı: Fen Bilgisi Öğretmen Adaylarının Öğretmenlik Uygulamalarında Kanıt Kullanımı Konusunda Güçlendirilmesi

Bilimsel kanıt, bilimsel bilgiyi geliştirmede bilimsel pratiklerin önemli bir bileşenidir. Ancak, fen bilgisi öğretmen adayları (FÖA), derslerine kanıtları entegre etme konusunda zorluklarla karşılaşmaktadır. Bu çalışmanın amacı, fen bilgisi öğretmen adaylarının bilimsel kanıtları kavramsal olarak anlamalarını geliştirmek ve kanıta dayalı açıklamaları derslerine dahil ederek öğretmenlik uygulamalarını zenginleştirmektir. Bu araştırmada, bir kamu üniversitesinin Fen Bilgisi Öğretmenliği programındaki okul uygulamaları dersi bağlamında, FÖA'lar için bir öğrenme ortamı yaratmak amacıyla tasarım tabanlı araştırma yöntemi kullanılmıştır. Öğrenme ortamı, sosyokültürel öğrenme teorisi, öğretmen öğrenmesine yönelik araştırmalar ve fen eğitimi literatürüne dayalı üç ilkeye dayanarak tasarlanmıştır; yapılandırılmış rehberlik sağlama, yansıtmayı kolaylaştırma ve öğrenme deneyimlerini anlamlı bağlamlarda konumlandırma. Bir pilot çalışma ile iki uygulama ve iyileştirme döngüsü gerçekleştirilmiştir. Nitel veriler; anketler, görüşmeler, okul uygulamalarının gözlemleri ve FÖA'lar tarafından oluşturulan ders planları aracılığıyla toplanmıştır. Bulgular, FÖA'ların kanıtları kavramsal olarak anlamalarında ve öğretim uygulamalarının kanıta dayalı dersler olma yolunda gelişiminde iyileşmeler olduğunu göstermektedir. Bu sonuçlar, üç tasarım ilkesinin FÖA'ların öğrenmelerini desteklemedeki rolünü vurgulamaktadır. Bu araştırma, iyi tasarlanmış öğrenme ortamlarının FÖA'ları kanıta dayalı dersler için gerekli pedagojik alan bilgisiyle nasıl donatabileceğini göstererek, fen bilgisi öğretmeni eğitime yönelik değerli içgörüler sunmaktadır.

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ABBREVIATIONS

BRH	Benzene Ring Heuristics Model
DBR	Design-Based Research
EE	Evidence Explanation Continuum
MEL	Model-Evidence Link Diagram
PCK	Pedagogical Content Knowledge
PST	Preservice Science Teachers



CHAPTER 1

INTRODUCTION

Teaching is a multifaceted endeavor that demands the consideration of numerous factors, including subject matter, pedagogical content knowledge, instructional materials, learning strategies, diverse student needs, and classroom interactions. Teachers play a key role in facilitating students' understanding of subject matter, fostering higher-order thinking skills, learning intricate issues, and reaching their utmost potential (Bransford et al., 2007; Darling-Hammond, 2008). However, research indicates that traditional teaching approaches fall short in educating individuals who fulfill these criteria (Geijsel & Meijers, 2005; Osborne, 2014). For this reason, the advancement of teacher learning has become a central concern in educational research (Darling-Hammond & Richardson, 2009; Hume et al., 2019; Le Cornu & Ewing, 2008).

Teacher learning is an ongoing process of becoming more knowledgeable about teaching. This lifelong journey begins during preservice education and extends throughout a teacher's professional career (Fishman et al., 2017). Research associates the quality of teaching in actual classrooms with preservice education that teachers received during early stages of their careers (Ballantyne, 2006; Darling-Hammond & Bransford, 2007). For this reason, preservice teacher education has gained considerable attention from scholars in the past two decades (Cochran-Smith, 2005; Darling-Hammond & Oakes, 2019; Loughran & Russell, 1997; van Driel & Abell, 2010).

Cognitive learning theories conceptualize learning at the individual level as acquisition of skills, knowledge, and understanding that can be transferred to various

contexts (Kelly, 2006). In preservice teacher education, cognitive learning theories are insufficient to facilitate meaningful learning experiences that correspond with real classroom experiences. Furthermore, it undermines preservice teachers' participation in learning communities, which provide opportunities for interaction, observation, and learning from expert teachers. Cognitive learning theories focus the development of individual knowledge around the transmission of theoretical subject matter and pedagogical knowledge. The decontextualized nature of learning creates a gap between the theory and practice of teaching (Mugaloglu & Doganca, 2009).

On the other hand, sociocultural learning theories propose that learning is rooted in social, cultural, and historical contexts (Nathan & Sawyer, 2014). Learners build social interactions with the environment through culturally organized activities that result in knowledge construction at both interpersonal and intrapersonal levels (Vygotsky, 1978). Additionally, knowledge is distributed across various elements within the learning environment, including teachers, peers, tasks, and artifacts (Pea, 2004). Sociocultural learning theories conceptualize teacher learning as peripheral legitimate participation in a community of practice (Lave & Wenger, 1991; Wenger, 1998).

Sociocultural learning theory highlights the learning process of novices involve interactions with more experienced individuals, promoting development of both cognitive and metacognitive skills (Collins et al., 1989). In teacher learning, the transition from peripheral participation as novice teachers to legitimate participation as expert teachers are supported by practicum courses of teacher training programs. In other words, bridging preservice teachers' learning process with experienced mentor teachers and faculty in university programs is a key objective in practicum courses (Cochran-Smith & Lytle, 1999). Practicum courses, by nature, require

preservice teachers to observe, participate, and practice in real classroom settings, followed by discussions and reflections in university courses. When purposefully designed, these courses facilitate collaboration among preservice teachers, university instructors, and mentor teachers, allowing them to engage in multiple communities of practice.

Training for PSTs should be grounded in a strong understanding of different forms of knowledge and their functions in science education, namely content, procedural, and epistemic knowledge (Osborne, 2014). While content knowledge is essential for science teaching, the cultivation of epistemic and procedural knowledge, along with an understanding of scientific practices, is necessary for fostering pedagogical content knowledge (PCK) (Duschl, 2003; Osborne, 2014). Epistemic practices in science are related to developing an understanding of “how we know what we know” (Duschl, 2008; Duschl & Grandy, 2013) through engaging with a set of processes to generate scientific knowledge and to evaluate knowledge claims (Erduran et al., 2021). These processes involve, but are not limited to, identifying patterns in data (Duschl et al., 2021), coordinating theory with evidence (Lombardi et al., 2013), reasoning with evidence (Kenyon & Reiser, 2006), constructing evidence-based explanations (Zemba-Saul, 2009) and argumentation (Jiménez-Aleixandre, 2007; Martin-Gamez & Erduran, 2018).

Epistemic practices are related to the dimensions of scientific literacy, which encompass understanding scientific knowledge, understanding the nature of science, and application of scientific practices (Miller, 1983). Central to the epistemic practices is the use of evidence. For example, scientific knowledge is developed based on collecting, organizing, and identifying scientific evidence. Both national (MEB, 2018, 2024) and international curricula (NGSS Lead States, 2013;

Department for Education [DfO], 2013) heavily emphasize the use of evidence in scientific and epistemic practices to understand the nature of scientific knowledge.

Although epistemic practices of science education has been an important focus for educational researchers (Duncan et al., 2018; Erduran et al., 2021; Erduran & Dagher, 2014, Duschl et al., 2021), teachers' understanding of epistemic practices (Martin-Gamez & Erduran, 2018; Saribas & Saka, 2018; Zembal-Saul, 2009) and students' use of evidence in coordination with claims (Berland & Reiser, 2009; Kuhn & Reiser, 2005; McNeill et al., 2006; Sandoval & Millwood, 2005) remains problematic. While PSTs participate in science methods courses where they engage with science content and receive training in pedagogical content knowledge strategies, the integration of epistemic practices into their teaching during practicum courses remains insufficient.

Teachers are expected to incorporate evidence into their lesson plans, teaching, classroom norms, and discourse. To achieve this, it is essential that they develop a comprehensive understanding of evidence, scientific inquiry, and scientific practices. Empowering PSTs to integrate evidence into their lessons and promoting an understanding of epistemic practices during preservice education can strengthen their teaching careers. In this regard, practicum courses offer a valuable opportunity to design a learning environment in collaboration with mentors, peers, and university faculty.

Design-based research (DBR) is a methodological framework in which design and research are intertwined to connect theory and practice (Bakker, 2019). In DBR, the design is grounded on theoretical foundations and principles drawn from prior research (Bakker, 2019; Cobb et al., 2003; Collins et al., 2004; McKenney & Reeves, 2012). From the perspective of learning sciences, DBR goes beyond merely

observing and describing natural settings. It aims to systematically engineer learning contexts to develop theories that address practical problems (Barab, 2014; Cobb et al., 2003; Collins et al., 2004; Bakker, 2019).

The current study is conducted as designed-based research to provide an insight into the learning process in developing PSTs' use of evidence in their teaching practices. It also allows observation of the design and learning outcomes of a practicum course systematically. In association with this, it is intended to provide guidelines for theory development on preservice science teacher education, rather than merely describing PSTs' proficiency in evidence-based instructions.

In line with sociocultural learning theory and teacher learning, key design principles of the current study are situating learning in a meaningful context, scaffolding, and reflection. Since learning and context are inseparable, people learn when working on authentic meaningful tasks (Brown et al., 1989). A meaningful learning context involves real-world events, problems, and settings (Collins & Kapur, 2014). In preservice teacher education, the practicum courses and school visits, where preservice teachers work with mentor teachers, provide such a meaningful context for learning. Observing expert teachers modelling teaching skills in classroom environments, alongside faculty guidance in university courses, facilitates the enculturation of preservice teachers into the community of practices of teachers (Brown et al., 1989).

Reflection is another learning principle that is emphasized in preservice teacher education. Reflection is a way of gaining awareness of one's own learning progress towards a goal or a complex situation, with the aim of making better decisions in future tasks (Dewey, 1938; Edelson & Reiser, 2006; Lin et al., 1999). Reflection plays a key role in making thinking visible by revealing implicit cognitive

processes of both experts and novices, enabling them to understand each other and the reasoning behind strategies that experts utilize (Collins et al., 1989). In preservice teacher education, various methods of reflection can be used to promote monitoring skills, such as follow-up sessions for practicum experiences (Loughran, 2002b), individual journal writing (MaKinster et al., 2006), video-cases of teaching practices (Abell & Bryan, 1997), and web-based tools for discussion (Barab et al., 2000). However, reflection may not naturally occur in learning environments and may require scaffolding learners' development of necessary reflective skills.

Scaffolding is a key characteristic in sociocultural learning theory. Grounded in Vygotsky's Zone of Proximal Development (1978), scaffolding refers to the support provided by a more knowledgeable other to help learners enhance their performance. In complex learning environments, distributed scaffolding addresses the diverse needs of learners by offering varying levels of support (Puntambekar & Kolodner, 2005). Social interactions between students and teachers also serve as scaffolding (Roehler & Cantlon, 1997). Scaffolding is important in teacher education because, rather than simply instructing preservice teachers on what to do, it guides them to construct their own knowledge of teaching through active engagement in the learning process (Sawyer, 2006).

In a nutshell, the purpose of the current study was to design a practicum course to empower PSTs in using scientific evidence in their instructions. The design of the learning environment was guided by teacher learning, science education, and sociocultural learning theory. Another major goal was to understand whether the elements of the learning environment (e.g., tools and tasks) function as intended and predicted. The design was situated in the context of a practicum course for PSTs at a

public university in Turkey. The design principles guiding the current research were as follows:

- scaffolding to facilitate PSTs' use of evidence and epistemic practices in their teaching
- reflection to promote PSTs understanding and use of evidence in science lessons,
- situating learning experiences in meaningful contexts to support PSTs' understanding and use of evidence in science lessons.



CHAPTER 2

LITERATURE REVIEW

This section begins with an overview of teacher learning, focusing on preservice teacher education and the role of reflection. It then examines sociocultural learning theory, highlighting the significance of scaffolding and meaningful contexts. Next, it explores the role of evidence in science and science education, emphasizing its importance in the curriculum. Finally, the purpose of the research is outlined, and the guiding research questions are presented.

2.1 Teacher learning

Twenty-first century calls for more complex and higher-order thinking skills beyond memorization of facts and procedures to survive the knowledge economy (Sawyer, 2006) and to participate in a democratic society (Cochran-Smith, 2005). Although teachers and students find opportunities to access various educational resources with the help of technological advancements in the digital age, teachers still play a key role in students' learning, especially in formal schooling (Bransford et al., 2007). Teachers' responsibilities extend beyond simply implementing the curriculum in the classroom (Bransford et al., 2007), as they also involve designing learning environments that actively support student learning (Akaygun & Aslan-Tutak, 2016). Given their critical role in students' learning, teachers must be well-prepared to teach in classrooms to foster their students' development of complex skills. Robust teacher education programs are necessary to foster learning how to teach in innovative and sophisticated ways, ultimately enhancing student learning outcomes through

meaningful and challenging experiences. (Cochran-Smith, 2005; Darling-Hammond, 2008; Darling-Hammond & Richardson, 2009).

Parallel to these expectations, the educational research community has shown great attention to teacher learning (Darling-Hammond & Oakes, 2019; Kelly, 2006; Loughran & Russell, 1997; Olsen & Buchanan, 2017; van Driel & Abell, 2010, Ertaş & Aslan-Tutak, 2021). Teacher learning refers to the process of learning to teach and acquiring the essential knowledge and skills for effective teaching.

Teacher learning is evidently an enduring journey throughout teachers' careers. Fishman, Davis, and Chan (2014) categorized teacher learning in terms of three career phases. The first phase, preservice teacher education, takes place in university programs and is commonly referred to as teacher education. The second phase encompasses the early years of a teacher in classrooms, often described as induction into teaching. These two phases primarily focus on novice teachers' learning to teach (Loewenberg Ball & Forzani, 2009). The final phase, in-service teacher education, refers to the ongoing development of teachers throughout their careers, commonly known as professional development.

2.1.1 Preservice teacher education

Preservice teacher education serves the purpose of preparing prospective teachers for effective teaching. The initial steps taken during their first phase, in preservice education, inoculate the development of important and expected characteristics of teachers. Teacher education programs should be designed to empower preservice teachers. The notion of pedagogical content knowledge (PCK) (Shulman, 1987) provides guidance to teacher educators on types of knowledge that preservice teachers should be equipped with. According to Shulman (1987), PCK is the

intersection of content knowledge and pedagogical knowledge that reflects a teacher's comprehension of how specific subject matter topics, problems, and issues can be structured, represented, and tailored to accommodate the varied interests and abilities of learners, subsequently facilitating instruction. Teacher education programs should not only facilitate learning PCK but also be designed to promote the skills necessary for teachers to improve student learning and their own teaching practices. Additionally, these programs should foster professional commitments to ensure that every child achieves their potential and encourage teacher participation as a collective member of the teaching community (Bransford et al., 2007). Finally, it is highly suggested to provide teachers with opportunities, before entering the profession, to experience different types of learning methods and pedagogical approaches they intend to or expected to teach students (Beattie, 1997; Magnusson et al., 1999).

As teachers' careers start with preservice teacher education, it is important to imbue learning to become an active member of the teaching community in these early stages. The importance of becoming a member of a teacher community of practice and designing learning environments to facilitate this participation has been highlighted in several studies (Dennen & Burner, 2008; Sumsion & Patterson, 2004; Mitchell & Wakefield, 2010; Pop et al., 2010). Preservice teacher education provides a valuable opportunity for novices to experience such multiple communities of practice through both university and K-12 school experiences. (Kang & van Es, 2019). When preservice teacher learning is situated in learning communities, such courses enable collaborative problem solving, sharing multiple perspectives and experiences, and socializing (Cochran-Smith & Lytle, 1999). Being a member of a

learning community assists in becoming a lifelong learner who questions their teaching and seeks for innovative answers (Cochran-Smith & Lytle, 1999).

The quality of preservice teacher education programs is a concern in several countries such as Australia (Le Cornu & Ewing, 2008), US (Cochran-Smith, 2005), and Turkey (Uygun et al., 2011). Cochran-Smith (2005) identified teacher education programs as a public policy problem. Le Cornu and Ewing (2008) examine concerns regarding teacher learning in Australian practicum courses, identifying three common approaches: traditional, reflective, and learning communities. They argue that individual reflective practice alone is insufficient for addressing challenges in teacher learning. Beyond individual development, they emphasize the value of contributing to others' learning within a community of learners, enhancing both individual and collective growth.

Practicum courses in Turkey face significant challenges, as school experiences and teaching practices are not effectively implemented, limiting preservice teachers' opportunities for meaningful learning (Uygun et al., 2011). To address this, the Higher Education Institution restructured practicum courses in 2018, requiring preservice teachers to engage in school-based teaching practice for two semesters during their final year (YÖK, 2018). These courses are designed to facilitate joint evaluation of preservice teachers by both mentor teachers and university faculty, fostering collaboration among all stakeholders. Under the revised framework, preservice teachers are expected to observe domain-specific teaching strategies, engage in microteaching, develop teaching materials, manage classrooms, assess student learning, and reflect on their practices (YÖK, 2018). Designing preservice teacher education courses in this manner strengthens the connection between preservice teachers, experienced mentors, and university educators,

enhancing their learning (Cochran-Smith & Lytle, 1999). Therefore, practicum courses are an indispensable component of preservice teacher training programs.

2.1.2 Reflection in teacher learning

There is a consensus that reflection is a critical component of teacher learning (Korthagen, 2010; Loughran, 2002a; Mathew et al., 2017). Based on the revised definition of practicum courses in Turkey (YOK, 2018), reflection is incorporated into practicums. Reflective thinking is a case of a particular problem or issue to be resolved (Dewey, 1938). To learn from this problem or issue, learners need to alter their beliefs, understandings, and actions through reflective thinking (MaKinster et al., 2006). Originated from the works of Schön (1983, 1987), reflection has gained attention as an important link to develop teaching practices.

Schön (1987) defines reflective teaching as an ongoing process in which teachers assess how their knowledge of teaching is applied in their own practice. Loughran (2002a) highlights that teaching-related challenges are often addressed through routine, taken-for-granted solutions. However, genuine improvements in teaching require addressing the root of these challenges through reflective practice. Schön (1987) categorizes reflection into three types: reflection-on-action, which occurs after teaching; reflection-in-action, which takes place during teaching; and reflection-for-action, which happens before teaching. Reflection-in-action is generally considered as a challenging task for novice teachers (Korthagen, 2010). Loughran (2002b) highlights that it requires simultaneous attention to “seeing” and “action” during teaching practice to make decisions and filter actions (p. 37).

In preservice teacher education, follow-up sessions arranged after practicum are a useful way to promote learning from experience since presenting their

experiences back to them may bolster realizing what they did not encounter during their practice (Loughran, 2002b). However, if these follow-up sessions remain on surface level to share interesting experiences, the outcome may not be as expected. These shared experiences should be accompanied by developing assertions about their practice, documentation to share with peers. During these processes, it should be noted that reflection may not occur naturally. In fact, learners may not even recognize the need for monitoring their learning process in the first place (Edelson & Reiser, 2006). This is to say that preservice teachers need to learn how to reflect on their own experiences and monitor their own learning process. For this reason, educators should think through how to teach their novice preservice teachers to make reflection (Korthagen, 2010). Designing multiple tasks to experience reflection is suggested to help learners realize the importance and the need to make reflection (Edelson & Reiser, 2006).

The social context of reflection plays a significant role in enhancing its effectiveness. MaKinster et al. (2006) examined the impact of social context on preservice science teachers' reflections in three distinct online forums, each designed with different learning theories. In the first forum, students wrote individual reflective journals based on an individualistic cognitive approach. The second forum incorporated feedback from instructors and peers, following a social constructivist perspective. The third forum, grounded in situativity theory, included feedback from instructors, peers, and experienced in-service teachers. The results revealed that while all three reflection types were beneficial, the social contexts shaped different norms and expectations for reflection and participation. In the first group, students wrote more complete reflections but did not find them valuable nor internalize them for future application. In contrast, students in the second and third groups, who

engaged in both individual and social reflection, valued the learning process more. These students sought more feedback and discussion, gaining new perspectives, though they focused less on solving problems and more on providing solutions to their peers.

The findings of MaKinster et al. (2006) align with those of Barab, Squire, and Dueber (2000), who created a web-based environment to foster collaboration between preservice and in-service teachers. The results revealed that collaboration with experienced teachers allowed preservice teachers to actively engage in a teacher community, contributing their experiences and skills. This collaboration helped them move beyond merely completing course assignments, providing them with an authentic and meaningful learning environment where they participated in the teaching community and accessed valuable resources.

Considering these studies, it can be concluded that while individual reflection is valuable, diverse approaches should be employed to promote reflection in preservice education. Encouraging discussions and social interaction, as well as providing opportunities to engage with experienced teachers within a supportive learning community, are effective examples to enhance the reflection process and cultivate it as a lifelong skill (MaKinster et al., 2006; Jasper, 2003).

Practicum as a university course is a suitable environment to provide preservice teachers a social environment to communicate with experienced teachers and an authentic environment of teaching practice with students in classrooms. In addition, peers in a university course environment provides a means to establish a learning community that can continue during their future careers. However, to establish this, the design of preservice teacher courses should elegantly consider

integrating various elements of the learning environment to promote building this learning community.

The proposed study takes teacher learning literature into consideration in the design of practicum courses for science teachers. As the role of reflection highlighted in teacher learning, it was one of the guiding design principles of the current study.

2.2 Sociocultural learning theory

Cognitive learning theories conceptualize learning as acquisition of skills, knowledge, and understanding that resides in individuals. Although learning is viewed as decontextualized in cognitive theories, it is assumed that learners can transfer skills, knowledge, and understanding in other settings to use (Kelly, 2006). However, from the learning sciences perspectives, cognitivism is challenged with the existence and role of social context in which knowledge and cognition is distributed across participants, materials, and resources. As for preservice teacher education, cognitive theories are insufficient to provide meaningful learning experiences aligned with real classroom experiences and participation in learning communities among which preservice teachers have a chance to interact with, observe, and learn from expert teachers. This is mainly because the focus of developing individual knowledge is centered around transmission of theoretical subject matter knowledge and pedagogical knowledge. The lack of contextualization in learning results in a disconnect between teaching theoretical understanding and its practical application in the classrooms (Mugaloglu & Doganca, 2009).

According to sociocultural learning theory, learning is considered as a social and cultural process (Barab et al., 2000; Fosnot & Perry, 2005). Sociocultural learning theory suggests that the learning process occurs in the knowledge of the

community and internalization of knowledge occurs after external experience gained through social interactions (Sawyer, 2006; Vygotsky, 1978). In other words, learners actively construct knowledge in individual minds as they make connections between their prior knowledge and new knowledge (Sawyer, 2006). Additionally, learners build social interactions within the environment, among whom they engage with culturally organized activities, play a significant role in this knowledge construction (Greeno, 2006; Lave & Wenger, 1991). The learning process is viewed not only as construction of knowledge but also enculturation into the practices of a wider society (Cobb, 1994; Driver et al., 1994).

The sociocultural learning theory has been heavily influenced by Russian psychologist Lev Vygotsky (1978). According to Vygotsky (1978), social, cultural and historical contexts play a significant role in learning and social interactions in the learning environment are mediated through language, signs, and tools. Vygotsky (1978) explains learning at two levels: First, learning at interpersonal level occurs through social interaction within the learning environment. Then, learning at intrapersonal level occurs. Intrapersonal level refers to individuals' internalization of knowledge in their cognitive structures.

2.2.1 Scaffolding

Vygotsky (1978) also proposed the concept of Zone of Proximal Development (ZPD) to explain the relations between development and learning. ZPD is defined as “the distance [between] the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers” (Vygotsky, 1978, p. 86). Based on the notion of ZPD, interactions with peers and

scaffolding from the instructor play critical roles in learning. Scaffolding is defined as the “process that enables a child or novice to solve a problem, carry out a task or achieve a goal which would be beyond his unassisted efforts” (Wood et al., 1976, p. 90). In other words, scaffolding is associated with the support provided to learners to increase their performance from knowledgeable others.

Vygotsky (1962) also highlighted scaffolding as “what a child can do today in co-operation, tomorrow he will be able to do on his own” (p. 87). This implies two key aspects of scaffolding: First, scaffolding should provide help to accomplish the given task, and second, improve the performance so that the learner becomes able to perform alone in future tasks (Reiser, 2004; Quintana et. al., 2004; Puntambekar & Hübscher, 2005). Puntambekar & Kolodner (2005) suggested the use of distributed scaffolding for the dynamic and complex nature of learning environments which require more than one type of scaffolding. This is to say that scaffolding should be distributed among several agents that lead to learning and these scaffolding tools constitute a system that integrates the tasks learners should complete (Pea, 2004; Tabak, 2004). In addition to teaching scaffold as a more knowledgeable other, other scaffolds could be for instance peers (Guzdial, 1994), curriculum (Cazden, 2001), tasks (Tabak, 2004), software tools (Lin et al., 2012; Zembal-Saul et al., 2002).

2.2.2 Meaningful learning context

Situated cognition suggests that learning is situated in the context that it is used, meaning that the learning of conceptual knowledge is not isolated from the situations in which it is used (Brown et al., 1989). This knowledge can be understood when it is used in the authentic tasks of a particular domain (Brown et al., 1989; Lave, 1995). To achieve conceptual learning in meaningful contexts, it is suggested that novices

work with experts to undertake the tasks (Collins & Kapur, 2014). This enables novices to learn both to perform a task and think about it the ways experts of the domain do (Lave & Wenger, 1991). Situated cognition has at their core the following assumptions: (a) Learning is a social process; (b) expertise in a specific domain can be developed (c) meaningful learning is an active, constructive, and self- regulating process; and (d) learning activities should reflect real- world situations rather than decontextualized tasks (Shuell, 1986).

Learning conceptual knowledge in various contexts promotes deep learning of concepts and allows us to make memorable connections between the concepts and contexts (Collins & Kapur, 2014). Learning involves the practice of certain methods specific to purposefully selected tasks and utilizing them in diverse settings (Collins & Kapur, 2014).

In school learning, tasks to promote higher order thinking skills are lagging the expectations of what 21st century calls for from the learners to develop. Relying on factual knowledge from textbooks or teachers' traditional instructions are not adequate to solve problems and gain these skills, as well as resulting in fragmented conceptual knowledge. Collins et al. (1989) underscore that (p. 455):

- Learning conceptual knowledge, by which experts use to solve complex problems, is situated in the context of its use. Deep learning and relations between concepts and contexts enable learners to use knowledge in different contexts. The main focuses are the models of expert processes regarding the tasks and the situated learning.
- Guided experience facilitates learning cognitive and metacognitive skills and processes

Facilitating the enculturation process (Brown et al., 1989) enables preservice teachers to observe and model teaching skills demonstrated by expert teachers in the school environment as well as faculty teachers during the course. It also provides opportunities to gain feedback from experts and peers to adjust for necessary skills, to realize and continue effective implementation of skills, and to learn the norms of science classrooms and perform accordingly (Kardash, 2000).

Practicum courses situate preservice teachers learning in teaching practices (Putnam & Borko, 2000), curriculum, or video-based environments as meaningful contexts (Borko, 2004). The relation of knowledge to context is of critical importance because the growth of teacher knowledge that is not translated into practice may not yield as learning outcomes of students (Desimone et al., 2002; Fishman et al., 2003). Therefore, the social context of teacher learning should be designed effectively to promote meaningful learning experiences.

2.3 Evidence in science and science education

2.3.1 The significance of evidence in science

The purpose of science is to develop scientific knowledge to understand and explain natural phenomena (Sinatra & Lombardi, 2020, Martin, 2003, Osborne & Patterson, 2011). Three fundamental questions guide scientists in this process: “What is nature like? Why does it happen? How do we know what we know?” (Osborne, 2014, p. 580). Scientists generate scientific explanations to answer these three questions through constructing, evaluating, and revising models (Duschl, 2008) that provide consistent web of theories, laws, and principles (Erduran & Kaya, 2018; Can & Saribas, 2019).

Evidence is a critical component of developing scientific knowledge. An agreement should be made within the scientific community to establish the validity of scientific explanations. This occurs through the critical evaluation of evidence and the formulation of valid, sound scientific arguments grounded in evidence. (Osborne, 2014). Critical evaluation can be explained as the analysis of evidence to determine whether it supports a theory and how it supports or refutes alternative explanations (Lombardi et al., 2013). It is important to recognize the dual role of evidence, as it can both support and refute a claim. Contradictory evidence holds as much strength as supporting evidence in judging the relationship between the evidence and the claim. (Lombardi et al., 2013).

Understanding the nature of science requires understanding that scientific knowledge is grounded in empirical evidence and subject to revision as new evidence emerges. (Lederman, 2006). Theories, laws, and models are developed in light of evidence, working in harmony to advance scientific knowledge and to deepen scientific understanding (Kaya & Erduran, 2016). In the pursuit of scientific knowledge, scientists use inquiry as the fundamental instrument to interpret and explain nature (Osborne, 2014). Scientific inquiry is essentially a process of exploring nature by formulating questions, developing methods to collect data about natural phenomena, and analyzing and interpreting the data to draw evidence-based explanations (Sandoval & Millwood, 2005). Moreover, a key aspect of the nature of science is its tentativeness (Lederman, 2006), meaning that scientific explanations can be revised as new evidence emerges (Windschitl et al., 2008). According to Karl Popper's concept of falsification, all scientific ideas must be falsifiable, meaning that although they cannot be definitively proven, they can be disproved when confronted with opposing evidence (1963). In light of this, the relationship between evidence

and scientific claims must be critically evaluated, followed by argumentation to support their connections (Lombardi et al., 2013). In the post-trust era, where personal beliefs and emotions often take precedence over scientific explanations, the spread of misinformation and disinformation has significantly increased over the past decade (Sinatra & Lombardi, 2020). Consequently, understanding the distinction between science and pseudoscience is essential for informed individual and collective decision-making (Chinn et al., 2020), especially on issues related to science such as the COVID-19 pandemic or climate change.

The role of scientific evidence is critical in the demarcation between science and pseudoscience, particularly to address such science-related issues (Erduran, 2021). As a recent example, during the COVID-19 pandemic, individuals were bombarded with an overwhelming amount of information, including both news and fake news (Barzilai & Chinn, 2020), with constant updates based on new research. The rapid spread of misinformation, often disguised as scientific fact, significantly impacts public health decisions, including vaccine hesitancy (Sinatra & Lombardi, 2020). Osborne (2014) highlights that one of science's key contributions to society is “building a commitment to evidence as the basis of belief” (p. 580), which in turn promotes “rationality, critical thinking, and objectivity” (p. 580). The pandemic crisis has shown the importance of scientific knowledge in people’s lives and epistemic practices to make evidence-based decisions. In conclusion, evaluating the validity of evidence gains priority in highly debatable socio-scientific issues (Kabapinar, 2019) and multifaceted and abstract concepts (Lombardi et al., 2018).

2.3.2 The role of evidence in scientific practices

Scientific knowledge is developed in a process (Martin et al., 1997) that requires the use of a set of practices to extend and refine that knowledge (NRC, 2012). Scientific practices refer to both the necessary skills and knowledge of each practice demonstrated in scientific investigation (NRC, 2012). This indicates that skills and knowledge need to be coordinated together to understand what, why, and how of science (Sinatra & Lombardi, 2020). There are 8 scientific practices in the K-12 framework for Science Education (NRC, 2012):

1. Asking questions and defining problems,
2. Developing and using models,
3. Planning and carrying out investigations,
4. Analyzing and interpreting data,
5. Using math and computational thinking,
6. Constructing an explanation (for science) and designing a solution (for engineering),
7. Engaging in an argument from evidence,
8. Obtaining, evaluating, and communicating information

Erduran and Dagher (2014) introduced the Benzene Ring Heuristic Model (BRH) to illustrate the interconnections among scientific practices (p. 82). The BRH comprises six components of scientific practices, illustrating the interconnections between the epistemic, cognitive, and social dimensions of science from a holistic perspective. The components of the BRH are real world, prediction, explanation, model, data, and activities (Figure 1).

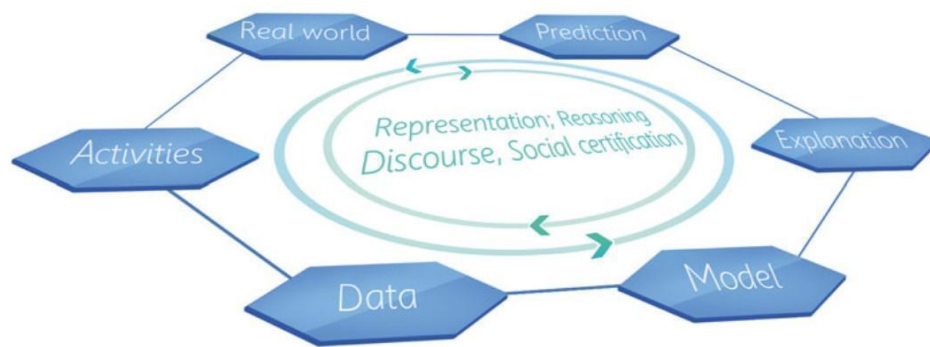


Figure 1. The benzene ring heuristics model

Among the components of BRH, data is the focus of the present study. Data refers to discrete reports of existing information or knowledge that are presented in suitable form for better usage or processing (Brown et al., 2010). When data is interpreted to construct a scientific explanation in a specific context, it is considered as evidence to support or refute an explanation scientifically (Brown et al., 2010). Hence, at the core of epistemic and scientific practices lies the use of evidence to develop scientific knowledge. In other words, scientific knowledge is developed based on identifying and evaluating scientific evidence in relation to scientific explanations. The link between explanation-data and data-model leads to generating scientific knowledge. When patterns in data are identified, a connection is made either to existing models or to the generation of new models that explain natural phenomena. Understanding this process helps learners engage in epistemic practices (Muğaloğlu et al., 2017).

2.3.2 The role of evidence in science education

In the post-truth era, statements and opinions that lack empirical support and misleading reasoning are frequently framed as scientific knowledge (Akşit et al., 2023). This trend undermines well-established scientific explanations and compromises informed decision-making on science-related issues (McIntyre, 2018;

Prado, 2018). The post-truth era conditions, together with the dilemmas of scientific developments, recall high quality science education to raise well-equipped citizens with critical thinking skills.

The aim of science education is to raise scientifically literate citizens who can make informed decisions (Driver et al., 2000). Although there is no consensus on the definition of scientific literacy (Feinstein, 2011; Holbrook & Rannikmae, 2009), it is generally agreed that it reflects the role of individuals in society as responsible citizens who make scientifically informed decisions. Making such decisions involves not only having a sufficient level of scientific knowledge (Holbrook & Rannikmae, 2009) but also critically evaluating evidence (Lombardi et al., 2013). Program for International Student Assessment (PISA), a world-wide event developed by Organization for Economic Co-operation and Development (OECD) defined the scientific literacy as; “The capacity to use scientific knowledge, to identify questions and to draw evidence-based conclusions in order to understand and help make decisions about the natural world and the changes made to it through human activity” (OECD, 1998). It is evident that understanding the role of evidence is a key component to understanding the nature of science and scientific inquiry.

To make informed decisions, the characteristic of scientific literacy underscores the importance of epistemic practices in general and the use of evidence in particular. Science classrooms designed to integrate the use of scientific evidence and epistemic criteria serve as an important building block to cultivate a scientifically literate society. In other words, science education aims to facilitate students’ learning to understand a body of existing scientific knowledge that is consensually agreed on by the scientific community (Osborne, 2014). Understanding how such scientific knowledge is produced is necessary. Briefly, three goals of

formal science education, namely conceptual, epistemic, and social goals were stated by Duschl (2008, p. 277) as follows:

- the conceptual structures and cognitive processes used when reasoning scientifically,
- the epistemic frameworks used when developing and evaluating scientific knowledge,
- the social processes and contexts that shape how knowledge is communicated, represented, argued, and debated.

Epistemic goals of science education refer to developing an understanding of how we come to know scientific knowledge and how they are built and supported. (Duschl, 2008; Duschl & Grandy, 2013). To establish this, students need to engage in scientific practices to understand how scientists make claims, as well as instituting validity and reliability for these claims through the critical evaluation of evidence (Osborne, 2014).

In science education, constructing evidence-based explanations, along with argumentation and critical evaluation, fosters the development of epistemic and scientific practices (Muğaloğlu et al., 2017; Can & Saribas, 2019). Moreover, the process of developing evidence-based explanations enhances understanding of the nature of science (Cengiz & Kabapinar, 2017; Can & Saribas, 2019), and cultivates an appreciation of scientific knowledge (Ceyhan et al., 2019). Engaging in scientific practices increases the cognitive demand and facilitate higher-order thinking skills through critical evaluation (Osborne, 2014). Ford (2008) underscored that scientific practices, scientific reasoning, and understanding content are linked to each other.

Kuhn and Pearsall (2000) define scientific thinking as ‘the consciously controlled coordination of theory and evidence’ (p. 113). Evidence-based instruction

can thus serve as a means of promoting scientific thinking in students. Critical thinking in science, essential for evaluating evidence, is fostered through argumentation and critique (Lombardi et al., 2013; Lombardi, Nussbaum, & Sinatra, 2016; NRC, 2012). Engaging in evidence evaluation helps students understand the epistemic frames of science—what scientists know and how they acquire knowledge—thereby enhancing their comprehension of scientific concepts through meaningful ways (Sinatra & Lombardi, 2020). This evaluation is particularly important in socio-scientific issues, where learners assess alternative explanations and make epistemic judgments (Sinatra & Lombardi, 2020).

A major problem in science education is that traditional science classrooms suffer from presenting factual knowledge to students and expect them to accept what is given as science (McNeill & Berland, 2017). This type of science education ignores the association between epistemic framework and the dimensions of scientific literacy, namely understanding nature of science, scientific practices, and use of scientific knowledge (Miller, 1983). In this case, the descriptive accounts of nature are provided to students without their cognitive engagement with epistemic and scientific practices since the explanations are already provided to them. Duschl (2008) described this type of science education as a content-process continuum that lacked the necessary connection between the content and the process, aiming to make students think like scientists by repeating the scientific method to test what has already been given them as knowledge. In time, this approach was challenged with the discovery-inquiry continuum in which the inquiry was at the center of science teaching (Duschl, 2008). In the United States, NGSS Lead Standards (2013) emphasized that science teaching should mainly focus on a process of inquiry and argumentation.

On the other hand, not all inquiry classes designed to engage the learner in epistemic practices of science (Chinn & Malhotra, 2002). In science classrooms simply repeating the inquiry cycles through cookbook style laboratory tasks reduces the cognitive engagement of learners (Osborne, 2014) as well as it reduces the diversity in thinking that leads to scientific reasoning (Duschl, 2003). In essence, this type of inquiry teaching lacked epistemic practices (Duschl & Grandy, 2008), since it focuses on developing causal explanations to why the phenomenon occurs (Osborne & Pattinson, 2011). The lack of epistemic frame, the efforts to explain ‘how’ we know what we know, has been problematic in science education (Newton et al., 1999). This problem has also been addressed in recent studies (Duschl et al., 2021; Erduran et al., 2021; Ioannidou & Erduran, 2021). In other words, the problem persists even though several educational reforms have been utilized, and formal curriculum documents address this issue (NRC, 2012; MEB, 2018, 2024; DfO, 2013). Teachers, who are responsible for implementing the curriculum and integrating evidence into science lessons to enhance student learning, should understand the role of evidence in science in the first place. The current research aims to address this problem of practice and seek a solution through facilitating science teachers’ understanding of epistemic practices and empowering them to use evidence in science.

2.3.3 Evidence in science education curriculum

Recent reforms in science education directed the focus of science teaching from conceptual knowledge to epistemic practices (Duschl, 2008) that can be more explicitly expressed as from exploration and experiment to argument and explanation (NRC, 2000). This shift brings an emphasis on the word ‘evidence’ in policy

documents such as in US (NGSS Lead States, 2013), UK (DfO, 2013) and Turkey (MEB, 2018). Epistemic practices play a key role in science education especially while teaching scientific inquiry (Duschl, 2003; Avraamidou & Zembal-Saul, 2005), scientific practices (Erduran & Dagher, 2014), and nature of science (Lederman, 2006). Use of evidence, at the heart of scientific inquiry and scientific practices, is heavily emphasized in international science curriculum such as Statutory Guidance for Science Programmes of Study in national curriculum of UK (DfO, 2013), and Next Generation Science Standards (NGSS Lead States, 2013) and A Framework for K-12 Science Education (NRC, 2012) in the United States.

To exemplify the scope of the national science curriculum of UK at Key Stage 3, following statement specifies the use of evidence: “Pupils should understand that science is about working objectively, modifying explanations to take account of new evidence and ideas and subjecting results to peer review” (DfO, 2013, p. 2). In addition, the document provides a section to describe “Working Scientifically” in terms of scientific attitudes, experimental skills and investigations, analysis and evaluation, and measurement (DfO, 2013, p. 4-5). It is mandatory for teachers to involve these elements throughout the year (which are described in detail in the document) to reflect the components of scientific and epistemic practices explicitly. For example: “present reasoned explanations, including explaining data in relation to predictions and hypotheses” (DfO, 2013, p. 4)

Similarly, the national curriculum of middle school science education in Turkey, implemented between 2018 and 2024, addressed science process skills and use of evidence explicitly, while referring to epistemic practices implicitly as for learning objectives (MEB, 2018). In 2024, the Turkish national science education curriculum was revised across all grade levels, and a reformed version was

introduced (MEB, 2024). The reformed version aims to cultivate individuals capable of applying science process skills, among other competencies. The curriculum explicitly outlines the focus as understanding the nature of science, the fundamental characteristics of science and scientists, and the evaluation of information source reliability. Additionally, students were targeted for practicing “making data-driven decisions” by focusing on the scientific perspective regarding real-life issues they encountered (p. 7). The curricular document explicitly addresses issues regarding the use of data and evidence with the following statement:

Students should be encouraged to collect scientific data by utilizing their skills. In this way, they can develop the ability to access various data sources, analyze this data, and make data-driven inferences. Students should also be guided to interpret and discuss the data they obtain and make generalizations based on scientific evidence, thereby strengthening their critical thinking, problem-solving, and data-driven decision-making skills (MEB, 2024, p.8).

Science process skills, while not explicitly stated, are integrated into various topics within the grade level objectives of the national science curriculum in Turkey upon closer examination.

Although there is so much attention on the use of evidence and science process skills in science education curricula, epistemic practices of science teaching remain problematic (Duncan et al., 2018; Duschl et al., 2021; Erduran et al., 2021). Research shows that students have difficulties in supporting scientific claims with evidence and provide justifications in their written scientific explanations (McNeill et al., 2006; Sandoval & Millwood, 2005), differentiating evidence drawn from data and the inferences made from the evidence with each other (Berland & Reiser, 2009). In addition to these problems, the field lacks an agreement on an understanding of what counts as evidence (Martin-Gamez & Erduran, 2018; Duncan et al., 2018; Manz, 2016) and its use in science teaching (Avraamidou & Zembal-Saul, 2010; Duschl 2008). Thus, evidence is used in several activities with various

meanings (McNeill & Berland, 2017). To identify and propose solutions regarding use of evidence, recent studies suggest frameworks to guide the design of science lessons (Duncan et al., 2018; Duschl et al., 2021; Manz, 2016; McNeill & Berland, 2017; Samarapungavan et al., 2018).

2.3.4 Frameworks for evidence integration in science lessons

To promote students' scientific reasoning, it is crucial to facilitate data collection, analysis, and exploration of the link between evidence and claims (Muğaloğlu et al., 2017). Integrating evidence into science teaching creates a learning experience that facilitates epistemic skills by sharing scientific knowledge (Muğaloğlu et al., 2017). A learning environment designed from this viewpoint allows students to investigate scientific evidence and reflect on its association with their prior knowledge, facilitating the co-construction of knowledge, while teachers can explore and analyze students' alternative conceptions through the knowledge-evidence link (Muğaloğlu et al., 2017).

McNeill and Berland (2017) identified three main problems of practice while using evidence: using science as the final form of ideas, using data as the answer, and isolating individuals and ideas in the learning environment. They proposed three design heuristics as a set of instructional guidelines to address these issues. The first design heuristic, a phenomena-based approach, counters the tendency to view science as a final form by linking scientific concepts to real-world phenomena, thus situating science in context through empirical data. The second design heuristic, transformable, emphasizes the transformation and evaluation of information. Transformation occurs when patterns in data are identified and evaluated in relation to the claims. This ensures that students use data for sensemaking rather than mere

memorization. The third design heuristic, dialogical, stresses the importance of social interaction and critique in making sense of nature, promoting collaborative knowledge building through discourse.

Along with the reforms, Duschl (2003, 2008) described an alternative framework for science lessons, the Evidence-Explanation Continuum (EE), that involves three steps of data transformations during the use of evidence during scientific knowledge building. Later, Duschl, Avraamidou and Azevedo (2021) revised this model and defined five transformations of data related to the use of evidence to construct scientific explanations. As Evidence-Explanation Continuum highlights the importance of representation, communication, evaluation, and dialectical discourse, it mainly aims to ‘engage learners in conversation of inquiry’ (Duschl et al. 2021, p. 279). Transformations in Evidence-Explanation Continuum are presented in Figure 2.



Figure 2. Evidence-explanation continuum

In each transition, an evaluation needs to be made to determine ‘what counts’ as evidence. As Popper (1963) expressed, any data can be used to support several theories. In line with this, Osborne (2014) underscored that data does not speak for itself, hence it is necessary to identify the proper data in relation to the context of its use to become evidence. How raw data selected and analyzed to be evidence, how evidence is selected and analyzed to generate patterns and models, and how the

patterns and models are used for scientific explanations are important transitional practices in ‘understanding the nature and processes of scientific practices’ (Duschl, 2008).

Zemba-Saul (2009) conducted design-based research to facilitate PSTs’ understanding of explanation structure and scientific reasoning through the argumentation framework. They conducted the study within the science methods course where the preservice teachers had a chance to observe and practice teaching in a school environment. Collected data at the beginning of the study has shown that most of the participants perceived science lessons as fun hand-on activities, lacking the necessary understanding to identify elements of an evidence-based lesson plan. The findings of the study have shown that argumentation framework purposefully scaffolded preservice teachers’ thinking skills and practice, as well as fostering them to focus on constructing evidence-based explanations. Based on the findings, Zemba-Saul (2009) also suggested that preservice teachers must consider the role of evidence, explanation, and argumentation in the science classroom and how to incorporate these important scientific practices into their own teaching to improve their own professional development in argumentation.

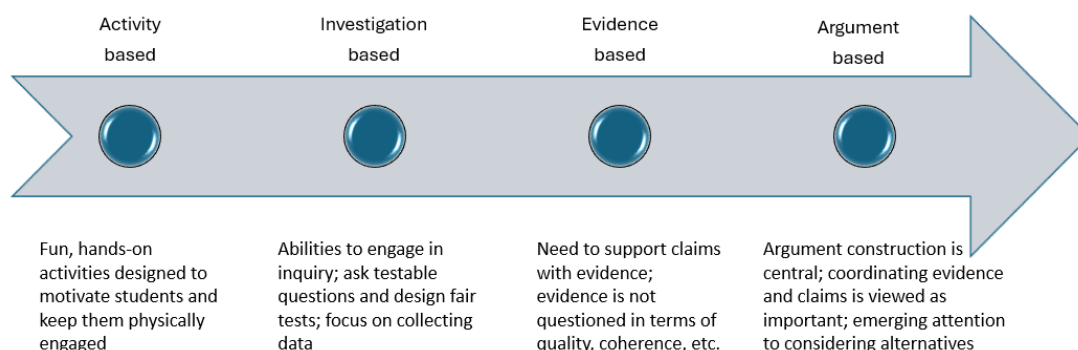


Figure 3. Continuum for teaching science as argument

Zemba-Saul (2009) described a continuum for teaching science as argument (Figure 3). The continuum, from left to right, indicates the level of cognitive engagement in the designed instructions of teachers. Figure 3 also shows the number of preservice teachers per each type of instruction they prepared prior to participating in the study.

2.3.5 Challenges in integration of evidence into science lessons

Integrating epistemic practices into science lessons is a challenging task, even when using one of these models, and requires support through various educational materials. Muğaloğlu et al. (2017) noted the limited availability of resources that focus on epistemic practices, criticizing that course materials often prioritize scientific content over these practices. The Model-Evidence Link (MEL) Diagram, developed by researchers at Rutgers University through the NSF-funded PRACCIS project (Chinn & Buckland, 2012), is an instructional scaffold for promoting conceptual learning and epistemic practices. Further versions of MEL diagrams, such as those for climate change, were developed by Doug Lombardi and his colleagues (Lombardi et al., 2018).

The MEL aim to promote the virtue of scientific thinking by comparison of two models for a scientific phenomenon (Lombardi, Danielson, & Young, 2016), help identify students' alternative conceptions on a given topic and foster conceptual change (Lombardi et al., 2013). While the original MEL diagrams are in English, some have been translated and adapted to Turkish by researchers (Can, 2017; Saka & Sarıbaş, 2019; Saribas & Ceyhan, 2015). Preparing, sharing, and facilitating such materials within a learning community not only enhances science education by promoting epistemic practices but also serves as a model for generating new educational resources.

Another way that curriculum developers and teacher educators may support teachers' understanding of scientific explanations is to provide them with examples of student responses to help them see the range of explanations that students might give as well as commentary along with examples of strong and weak explanations (McNeill & Krajcik, 2008; Remillard, 2000). Enabling teachers to critique the different components of a scientific explanation may help them develop an understanding of what counts as a high-quality explanation and its association with evidence.

Another key challenge to integrate evidence into science lessons is teachers' readiness to facilitate students' engagement with epistemic practices and understanding of evidence. Research indicates that teachers often struggle to understand epistemic practices themselves (Erduran et al., 2021) and to support students' development of evidence-based explanations (Newton et al., 1999; Sampson & Blanchard, 2012). Therefore, teachers must first develop an understanding of evidence and epistemic practices, while also refining instructional strategies to help students construct evidence-based explanations. (Ann Haefner & Zembal-Saul, 2004; Newton et al., 1999).

An example of difficulties teachers encounter on understanding and use of evidence is research conducted by Saribas and Saka (2018) using MEL diagrams with in-service teachers. The results indicated that although teachers built proper model-evidence links, they generally based their decision on their content knowledge rather than critical examination. In another study, Sampson and Blanchard (2012) interviewed 30 middle and high school teachers about epistemic practices. The results showed that sometimes teachers face challenges in using evidence and sometimes they confuse evidence with an explanation as they rely on their subject

matter knowledge instead of data. Thus, the result is associated with the fact that teachers lack necessary understanding on this issue.

Beyer and Davis (2008) conducted a case study with a beginning elementary teacher to explore her understanding and beliefs of constructing scientific explanations and her instructional strategies to promote student learning. The results revealed that the teacher had two distinct understandings of scientific explanations. Moreover, evidence was not considered a critical component of these explanations, as she did not fully comprehend the role of evidence in generating scientific explanations. Results indicated that she primarily focused on supporting claims with additional details, without incorporating data or evidence. This limitation was also evident in her assessment of student work, where she mainly focused on the claims and only recognized evidence when explicitly prompted to do so.

Teacher education should foster learning diverse instructional strategies for constructing evidence-based scientific explanation and providing feedback to promote students' understanding of this process (Beyer and Davis, 2008). Teacher educators should incorporate examples of student-developed scientific explanations (McNeill & Krajcik, 2008) to help preservice teachers anticipate the variations they may encounter in the classroom. Encouraging critical evaluation of evidence-based explanations is also recommended to enhance teachers' understanding of epistemic practices (Beyer & Davis, 2008).

2.4 Purpose of the study and the research questions

The aim of the current study is twofold: The first aim is to design and implement a practicum course to empower PSTs and systematically evaluate the design and learning outcomes of the course. The second aim is to establish guidelines for theory

development on preservice teacher education and the nature of practicum courses, moving beyond merely describing preservice science teachers' proficiency in evidence-based instruction. The current study was conducted as design-based research to explore the learning process involved in enhancing preservice teachers' understanding and use of scientific evidence in their teaching—an essential component of scientific practices for advancing scientific knowledge. In line with these objectives, the current study was designed and implemented as a pilot study followed by two iterations. Both the pilot study and each iteration, along with the design principles guiding the practicum course will be explained in detail Chapter 4.

The current designed-based research was guided by the following research question:

How can a science teaching practicum course, designed with scaffolding, reflection, and meaningful learning principles, empower preservice science teachers to prepare and implement lesson plans enriched with evidence-based explanations as a component of the scientific practices?

The sub-questions are:

1. In what ways is PSTs' understanding of scientific evidence shaped during the designed practicum course?
2. How does the PSTs' use of scientific evidence in their lesson plans change by the end of the designed practicum course?
3. How does the PSTs' use of scientific evidence in their teaching practices change by the end of the designed practicum course?
4. In what ways does the designed practicum course mediate PSTs' learning to integrate scientific evidence as a crucial component of scientific practice into their teaching?

CHAPTER 3

RESEARCH METHOD

This chapter begins by explaining design-based research (DBR) as the methodological framework for the study. Next, it provides an overview of the research context and participants, followed by an outline of the DBR procedures used in the design of the research. The chapter then details the data sources for each cycle and the analytical frameworks employed for data analysis. Finally, the researcher's positionality and the trustworthiness of the study are discussed.

3.1 Design-based research

The purpose of this study was to facilitate PSTs' understanding of scientific evidence and to promote its use in their teaching. To achieve this goal, the current study was situated in a science practicum course at a public university and guided by sociocultural learning theory and teacher learning.

DBR is a methodological framework in which design and research are interwoven to bridge theory and practice (Bakker, 2019). In DBR, the design is grounded on theoretical foundations and principles drawn from prior research (Bakker, 2019; Cobb et al., 2003; Collins et al., 2004; McKenney & Reeves, 2012). DBR is conducted to develop theories to inform the problems of practice (Barab, 2014; Cobb et al., 2003, Collins et al., 2004; 2003; Bakker, 2019). The outcomes of the design, which could be in the form of humble theories (Cobb et al., 2003), contribute to developing domain-specific learning that works to solve real educational problems of practice (Cobb et al., 2003; Bakker, 2019). This reflects that DBR is pragmatic in solving real-world problems (Cobb et al. 2003).

Unlike naturalistic approaches that observe and describe a learning environment, DBR follows an interventionist approach by manipulating learning based on theories (Cobb et al., 2003; Bakker, 2019). Design of a learning environment involves sequential activities to promote learning and lead to suggest solutions to problems of practice in a specific domain (Bakker, 2019). Learning environments are complex systems in which all elements interact with each other and function together to facilitate the learning process (Cobb et al. 2003; Collins et al., 2004). This requires collecting multiple forms of data to understand how the elements of the learning environment function (Sandoval, 2014). For this reason, DBR allows researchers to collect qualitative and quantitative data when necessary. DBR has a cyclic process, meaning iterative (Cobb et al., 2003). After the design is implemented, necessary revisions are made based on analysis and evaluations. A reformed version of the design is implemented in the following cycle.

This study was conducted as design-based research to address the PSTs' problems of conceptualization in evidence-based explanations of science and seeks a solution through facilitating science teachers' understanding of evidence and empowering them to use evidence in their science lessons. Therefore, a preservice science teacher course was designed and implemented within the context of a practicum, including a pilot study and two iterations.

3.2 Research context and participants

The current study is situated in two practicum courses offered for senior PSTs. These courses are part of the BS in Science Education degree at a highly regarded public university in western Turkey. Both courses are mandatory for degree completion and

are taken consecutively by PSTs during the Fall and Spring semesters of their final year in the science education program. The medium of instruction is English.

These courses also qualify as an internship for each PST, which necessitates registering with a middle school and obtaining authorization from the Ministry of Education in Turkey. PSTs are expected to implement their teaching practices at least twice within a single semester at their registered K-12 schools. The first course taken by PSTs is Practice Teaching in Mathematics and Science (in Fall). It is an introductory course to the school environment involving critical observation of science classrooms, devising lesson plans, and implementation of two teaching practices under the supervision of an experienced science teacher in K12 school and a faculty member. The course also aims to familiarize PSTs with the overall school environment by involving them in observing various aspects of the school, including its organization, administration, daily routines, and challenges. The second practicum course, Practice Teaching in Science, involves observation of science classrooms at the implementation school, design of lesson plans, and supervised teaching in the classroom or laboratory as well. The regular length of each semester is 12 weeks. PSTs attend implementation schools to make observations for 6 hours per week. However, exceptional circumstances like country-wide earthquakes allow for minor adjustments to the number of course weeks. For the second cycle of the current research, the university authorities announced a shortened 11-week semester due to the earthquake in the country.

In line with the current research, PSTs engaged in the learning sessions of the designed program during their undergraduate courses. The sessions lasted two consecutive class hours (100 minutes) weekly. Additionally, the researcher/instructor observed two teaching practices implemented by PSTs in real K-12 classrooms to

furnish feedback and collect data. Each teaching practice session lasted 40 minutes. Prior to each teaching practice, PSTs designed lesson plans and convened with the researcher to obtain feedback on their plans.

Participants of the study were selected from voluntary undergraduate students (PSTs) enrolled in the two courses Practice Teaching Science and Practice Teaching in Mathematics and Science. Since the researcher also served as the instructor of the course, convenient sampling was employed. Participants ranged in age from 21 to 25 years. All registered PSTs have been included in the designed course and data collection process. The purpose of the study was explained to the PSTs both verbally during the class and in written form through the research consent form. All PSTs throughout all cycles signed the consent form for participation, which included video and audio recording of sessions as well as data collection procedures. The research, encompassing all cycles and data collection instruments, received approval from the Ethics Committee for Master and PhD Theses in Social Sciences and Humanities (SOBETİK) of the Social Sciences Institute of Boğaziçi University (For pilot study- Document Date and No: 10.04.2022-61403; for main research- Document Date and No: 04.10.2022-90837) (Appendix A and Appendix B).

Initially, convenient sampling was used since the researcher was the instructor of the courses. Participants were selected from registered students using purposeful sampling, based on two criteria: full participation in all data collection tools and attendance to the course sessions which specifically focused on conceptual framework of evidence and its role in science and science education, identified as Theme 1 of the program. Participants who did not meet the selection criteria or whose data collection was hindered by external factors were excluded from the analysis. These factors included unmet course requirements, health issues,

scheduling conflicts, incomplete teaching practices, and class absences. Table 1 displays the total count of PSTs enrolled in these courses and the number of participants eligible for data analysis.

Table 1. Number of Participants for the Pilot Study and the Cycles

Time	Undergraduate course	Medium of the course	Phase of the research	# of PSTs enrolled	# of selected participants
2021/22 Spring	Practice Teaching Science	Online platform	Pilot study	10	7
2022/23 Fall	Practice Teaching in Mathematics and Science	In-class	1 st Cycle	12	5
2022/23 Spring	Practice Teaching Science	In-class	2 nd Cycle	10	5

Given the richness of the data, narrowing the participant pool enabled a deeper exploration of individual experiences and more meaningful interpretations of the data. Participants chosen for data analysis were articulate, willing to engage in discussions throughout all activities, and enthusiastic about engaging in all data gathering tools, hence enhancing the richness of the data. Consequently, the pilot study was conducted in an online platform due to pandemic conditions and included seven female participants. The first cycle of the study was conducted in face-to-face class session in Fall 2022 as part of the practicum course Teaching Practice in Mathematics and Science. The first cycle included five PSTs (four female, one male). The second cycle of the study was conducted in face-to-face class sessions in

Spring 2023 as part of the practicum course Teaching Practice in Science. The data analysis encompassed five female participants from the second cycle.

3.3 Design-based research procedures

An important aspect of DBR is that it is iterative. A cycle of DBR consists of three important phases which are analysis and exploration, design and construction, and evaluation and reflection (McKenney & Reeves, 2012). Upon completion of each cycle, new conjectures are generated based on the evaluation of the cycle (Cobb et al., 2003), or previous conjectures are refuted. Necessary revisions are made in the design, and the next cycle is then implemented.

The current research, conducted as DBR, involved a pilot study and two cycles. The design and implementation of the pilot study, cycles, and the embodiments of design principles guiding the practicum course, will be explained in detail in Chapter 4. The DBR procedures followed in the current research were summarized in Figure 4.

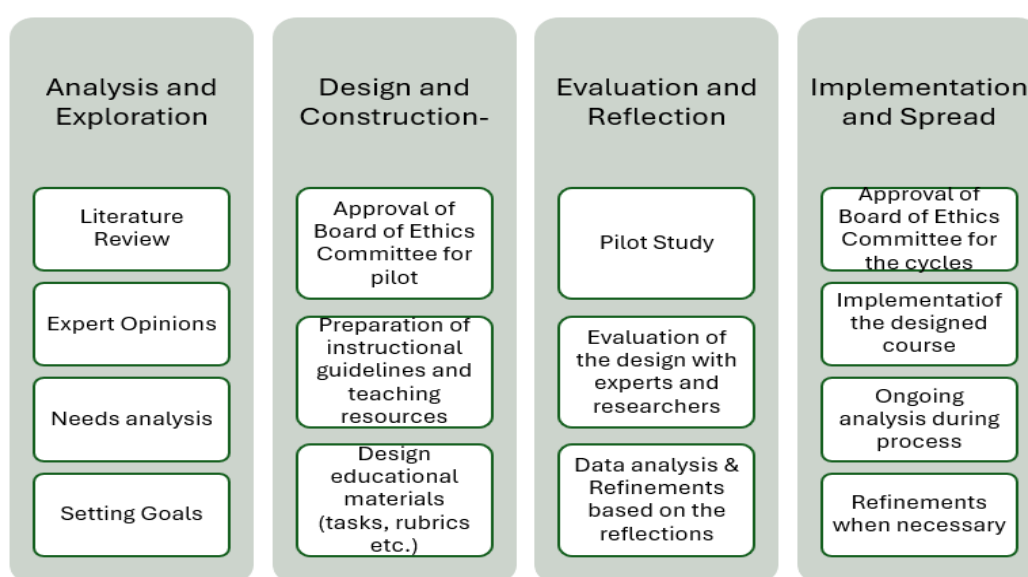


Figure 4. The flow of the design procedures

Analysis and Exploration: A comprehensive literature review was conducted, and expert opinions were sought to define the problem space in the educational context and assess preservice teachers' preparedness and needs. University instructors, researchers, and experienced science teachers provided insights as experts. These insights guided the establishment of clear and realistic goals within the constraints of the practicum course for PSTs. The needs analysis involved reviewing PSTs' lesson plans from prerequisite courses and observing and analyzing their initial teaching practices along with their related lesson plans in the Practice Teaching Science practicum. Additionally, their prior knowledge of epistemic knowledge was explored through an open-ended questionnaire to inform course design.

Design and Construction: Instructional guidelines and teaching materials were developed based on expert opinions and the relevant literature. The results from the questionnaire administered during the analysis and exploration phase guided the design of task structures and activities of the course. Finally, assessment tools and rubrics were generated for training of PSTs.

Evaluation and Reflection: The tasks prepared for the course were tested during the pilot study. The design of the learning environment was evaluated in collaboration with experts. Refinements were made to improve the design of the learning environment based on preliminary data analysis and the feedback and reflections of PSTs.

Implementation and Spread: In this phase, designed course was implemented with participation of preservice science teachers in two cycles. Ongoing analysis was conducted during the program implementation and revisions made between cycles.

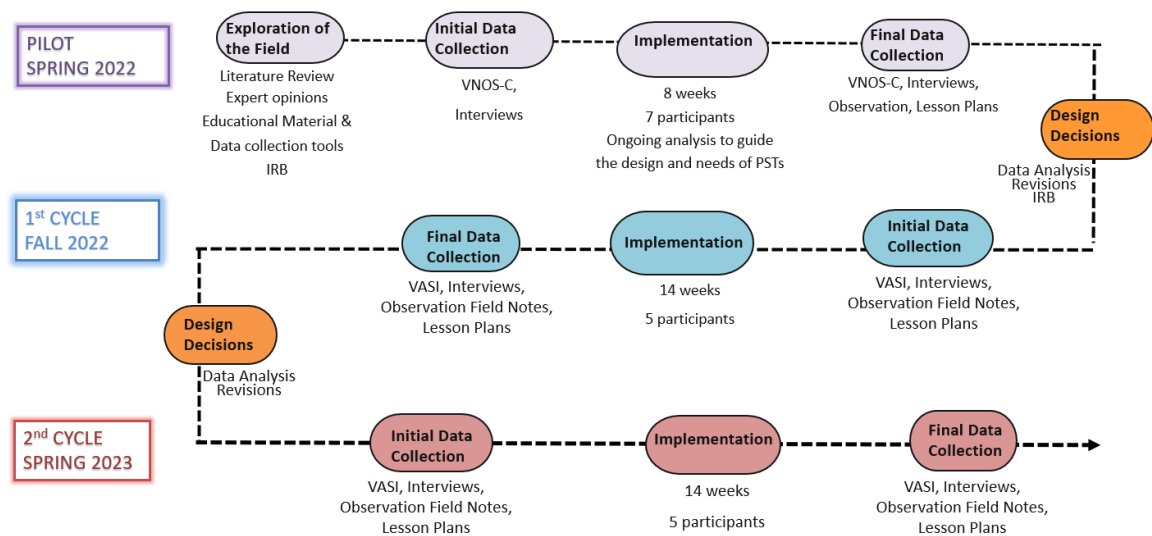


Figure 5. Flow of the research

Figure 5 illustrates the research flow from the pilot study to the second cycle and highlights key steps taken throughout the study. It also provides details on the number of participants, program duration, and data collection tools. The data collection tools will be discussed in detail in the next section.

3.4 Data collection

All data was collected in qualitative nature to explore PSTs' understanding and learning process in depth. Data collection tools included interviews, an open-ended questionnaire, lesson plans as artifacts, observations of teaching practices, and the researcher's field notes. The aim was to explore whether the design and learning outcomes were achieved. Throughout the research cycles, these tools were purposefully revised. Summary of the data collection tools in regard to the application time are displayed in Table 2.

Table 2. Summary of the Data Collection Tools

Phase of the Research	Data collection tools	Form of data	Time of application
Only in Pilot	VNOS-C	Written	At the beginning of the program
1st Cycle 2nd Cycle	Views about Scientific Inquiry Questionnaire (VASI)	Written	At the beginning and end of the program
	Demographic Information Form	Written	At the beginning of the program
	Reflection Interviews (Int1 and Int2)	Recorded & transcribed verbatim	At the beginning and end of the program
Pilot 1st Cycle	Program Evaluation Interview (Int3)	Recorded & transcribed verbatim	Upon completion of the program
2nd Cycle	Lesson Plans as artifact (LP1 and LP2)	Written	
	Teaching Practices observation notes (TP1 and TP2)	Written	During the program
	Field Notes of the researcher	Written	

For example, based on the pilot study, the questionnaire was replaced with one better suited to exploring participants' understanding of the topic. Interview questions were refined to ensure comprehensive coverage of key issues. Revisions before the first cycle were informed by the pilot study and expert feedback, while adjustments for the second cycle were based on the first cycle's implementation and input from field experts. These revisions primarily involved clarifying interview questions to enhance clarity and accuracy.

3.4.1.1 Demographic information form:

This form includes questions on participants' general information, such as name, gender, age, and education, as well as their access to science-related resources (e.g., scientific publications they follow) (Appendix C). It was administered before the program's implementation. Its aim was to understand the social and cultural contexts that shape participants' views on science and science teaching. Following the pilot study, this form was revised for the first and second cycles. The updated version, which included three additional questions on science capital, comprised 14 questions in total. Minor adjustments were made to enhance clarity, focus, and simplicity.

3.4.1.2 Views of the nature of science questionnaire form-C

The Views of the Nature of Science Questionnaire Form-C (VNOS-C) was administered during the pilot study at the beginning of the program's implementation. It aimed to explore participants' views on the nature of science and their understanding of evidence in science. Therefore, it served as a guide for making relevant connections during learning activities.

The VNOS-C consists of 10 open-ended questions designed to assess seven aspects of the nature of science (NOS) related to the growth of scientific knowledge (Lederman et al., 2002). Originally developed by Lederman, Abd-El-Khalick, Bell, and Schwartz (2002), it was later adapted into Turkish by Özcan and Taşar (2018) as the Bilimin Doğası Hakkında Görüşler Anketi. Özcan and Taşar (2018) also developed a rubric for evaluating responses to the Turkish version.

Two aspects of NOS—"scientific knowledge is empirically based" and "scientific knowledge is based on evidence and observation"—were particularly relevant to the focus of the current design and reflected in multiple questions. For

instance, one question asked the types of evidence scientists used to discover the atom, directly aligning with the objectives of the current design. However, other objectives were embedded more implicitly within the remaining questionnaire items.

3.4.1.3 The views about scientific inquiry questionnaire:

After analyzing the pilot study, VNOS-C was found to be limited in capturing participants' in-depth understanding of data and evidence. Since VNOS-C primarily explores epistemological beliefs about the nature of science (Lederman et al., 2002), the questions were not directly related or explicit enough for evaluating participants' conceptual understanding of evidence. For this reason, in the 1st and 2nd cycle, The Views About Scientific Inquiry (VASI) questionnaire was used instead of VNOS-C.

VASI items reflect the fundamental aspects of scientific inquiry which were more consistent with scientific practices in general and data and evidence in particular. VASI questionnaire contains seven contextualized open-ended questions and was developed by Lederman et al. (2014). It included an explicit question on the distinction between data and evidence, accompanied by an example, to explore participants' understanding of data and evidence. The original VASI questionnaire was translated and adapted to Turkish as 'Bilimsel Sorgulama Hakkındaki Görüşler Anketi' (Çavuş Güngören & Öztürk, 2016; Güngören, & Öztürk, 2021) (Appendix D).

This questionnaire was administered at both the beginning and end of the program to explore participants' conceptual understanding of data and evidence in relation to scientific practices. Its use at the beginning helped establish necessary connections during learning activities of the program. Its administration at the end

helped exploring participants' conceptual development and the consistency of their responses across the questionnaire and interviews.

3.4.1.4 Interviews

Each participant took part in three semi-structured interview sessions. The first interview (Int1) was conducted after their initial teaching practice (TP1) in the practicum course. This session was strategically scheduled before implementing the designed course activities to explore their understanding and use of evidence in lessons, their initial ideas about evidence in science learning and teaching, and to prompt reflection on their lesson plans and classroom practice. Additionally, insights from these interviews helped shape the course activities based on identified learning needs. The interview included 9 main questions with follow-up prompts (Appendix E).

The second interview session (Int2) was conducted after participants' second teaching practice (TP2) in the practicum course, which took place following the completion of the designed learning activities. This interview aimed to explore their understanding of evidence to use in science learning and teaching, encourage reflection on their teaching, and gather their perspectives on the practicum course design. Initially, Int2 included the same questions as the first. However, based on insights from the pilot study, first cycle, and contextual considerations, revisions were made by adding new questions. New questions targeted PSTs' understanding of the use of scientific evidence in their first lesson plans and teaching practices after participating in the program. As a result, the total number of questions increased from 9 to 11 in the final version (Appendix F).

The third interview session (Int3) was conducted at the end of the semester after the course was completed. It aimed to explore participants' views on the course design, gather feedback on the learning activities' contributions to their learning process, and gain insights for improving the study in the next research cycle (Table 2). Int3 included three questions (Appendix G). The first question was focused on reflecting on their development of conceptual understanding of data and evidence through the course. The second question focused on participants' evaluation of the main course activities with respect to the main themes and topics. The final question aimed to explore their perspectives on the feedback provided during lesson planning and teaching preparation. After the pilot study and the first cycle, minor revisions were made to simplify, focus, and clarify the questions.

Table 3. Details of the Interviews

No of interview	Timeline	No of questions	Duration	Purpose
1st interview	After TP1	9 main questions and follow-up questions	Avg 40 min	- explore PSTs conceptual understanding and use of evidence in their lessons - explore their initial ideas about the role and use of evidence in science education - facilitate reflection on their teaching and learning
2nd interview	After TP2	11 main questions and follow-up questions	Avg 60 min	- explore PST's understanding and use of evidence in their lessons - explore their understanding of the role and use of evidence in science education - facilitate reflection on their teaching and learning
3rd interview	At the end of the program	3 main questions and follow-ups	Avg 40 min	- to reflect on their own learning - to evaluate the design of the practicum course through the learning activities and their role in PSTs' learning process

3.4.1.5 Lesson plans as artifacts

Participants individually prepared two lesson plans aligned with MEB objectives during the practicum course. The first lesson plan (LP1) was created at the beginning of the course, while the second (LP2) was developed at the end of the program. These lesson plans, collected as data artifacts, were used to explore how PSTs integrated data and evidence into their science lessons and the strategies they employed. The lesson plan designs helped identify areas for improvement in participants' use of evidence, determine alternative approaches to enhance their lesson plans, and provide guidance throughout this process.

To structure their lesson plans, PSTs were provided with a lesson plan template and the 5E model as an instructional design to reduce their workload and allow them to focus on the content (Appendix H). This model was chosen because they were already familiar with it from their previous courses.

3.4.1.6 Observation of teaching practices

Participants prepared their LP1 and LP2 and implemented them in real classroom settings. The researcher observed their both teaching practices and took observation notes. It helped to understand how PSTs implement their lesson plans in a classroom environment and determine whether and in what ways use of evidence is reflected in their teaching practices. During observation, an expert opinion of an experienced science teacher was obtained in at least three sessions. Both the researcher and the expert observed the same lessons at the same time and took notes during observation. Their notes were compared to ensure trustworthiness.

A summary of the collected data in terms of categories and their forms is presented in Table 4.

Table 4. Summary of the Data Collected in the 2nd Cycle

Category	Data collection tools and data form
Participants' Data	• 1st interview (8 hours) (recorded) • 2nd interview (10 hours) (recorded) • 3rd interview (10 hours) (recorded) • 1st and 2nd lesson plans (written & recorded) • Observation of Science Lessons Task (written and recorded) • VASI (written) • Demographic Information Form (written)
Researcher's Data	• Field notes (written) • Observation of teaching practice_TP1 and TP2 (written)

3.5 Data analysis

This section focuses on data analysis related to preservice science teachers' conceptual understanding and use of scientific evidence. It outlines two analytical frameworks used to assess conceptual understanding of data/evidence, as well as the integration of data/evidence into lesson plans and teaching practice. Detailed data analysis was conducted for the data gathered from the 2nd cycle data sources. Data sources in relation to the research questions are displayed in Table 5.

Table 5. Research Questions and Associated Data Sources

Main Research Question: How can a science teaching practicum course, designed with scaffolding, reflection, and meaningful learning principles, empower preservice science teachers to prepare and implement lesson plans enriched with evidence-based explanations as a component of the scientific practices?	
Sub-Questions	Data sources
RQ1: In what ways is PSTs' understanding of scientific evidence shaped during the designed practicum course?	• VASI-1 and VASI-2 • Interviews (Int1, Int2, and Int3)
RQ2: How does the PSTs' use of scientific evidence in their lesson plans change by the end of the designed practicum course?	• Lesson plans (LP1 and LP2) (artifact) • Interviews (Int1 and Int2)
RQ3: How does the PSTs' use of scientific evidence in their teaching practices change by the end of the designed practicum course?	• Field notes of observation of 1st and 2nd teaching practices (TP1 & TP2) • Interviews (Int1 and Int2)
RQ4: In what ways does the designed practicum course mediate PSTs' learning to integrate scientific evidence as a crucial component of scientific practice into their teaching?	• Interview on program evaluation (Int3)

3.5.1 Conceptual understanding of data and evidence analytical framework

The Views of Scientific Inquiry Questionnaire (VASI) (Lederman et al., 2014) was employed as a data collection instrument to evaluate participants' conceptual understanding of data and evidence concepts. The items within the VASI were designed to reflect key components of scientific inquiry, aligning with general scientific practices, with particular emphasis on data and evidence. The questionnaire consists of seven open-ended questions, each contextualized to explore specific aspects of scientific inquiry. Notably, the fourth question requires participants to

articulate the distinction between data and evidence, accompanied by an illustrative example.

The VASI was administered to participants at two distinct stages: before the designed course started (VASI-1) and after it was completed (VASI-2). The primary goal was to assess participants' conceptual understanding of data and evidence, as well as their relationship to scientific explanations and practices. To achieve this, the BRH framework guided the initial coding process. The holistic perspective offered by BRH on scientific practices facilitated the identification of codes for the concepts of data, evidence, and the link between data and scientific explanations.

During the initial coding phase, responses from all PSTs in the first and second cycles were analyzed to create a codebook focused on the conceptual understanding of data and evidence. In the 1st cycle, 12 participants completed both VASI-1 and VASI-2, while 10 participants did so in the 2nd cycle. A total of 44 responses to the fourth question of the VASI were examined, contributing significantly to the codebook's development.

Throughout this phase, additional codes emerged, including those addressing the appropriate use of scientific terminology. These emergent codes were carefully integrated into the Codebook-1. Subsequently, a secondary coding phase was conducted, incorporating both codes derived from the BRH and the emerging codes. Final refinements were made to complete Codebook-1. Thus, both the theoretical framework and the emergent codes informed the development of Codebook-1, which systematically classifies levels of conceptual understanding of data/evidence into four distinct levels: Informed, mixed, naive, and unclear (Table 6).

Table 6. Codebook-1 for Conceptual Understanding of Data/Evidence

Level	Description/Criteria	Example
Unclear	No valid explanation or example of the concepts of data and evidence is provided.	Data is any data obtained, while the certainty of evidence has been verified. (Code Name: Eylül)
Naive	- Only one of the concepts—data or evidence—is explained or exemplified. - The relationship between data and evidence is not explained.	Data is systematic information collected through observation, experimentation, and various scientific ways. However, evidence is formed by proving this data. (Code Name: Element)
Mixed	- At least one of the concepts—data or evidence—is explained or exemplified. - The relationship between data and evidence is explained or exemplified. - Misuse of terminology - Misidentification of data/evidence in a lesson plan*	While all evidence is data, not all data is evidence. A portion of data, extracted from a large data pool through examination and processing, can be evidence. We call the data related to our problem, theory, or hypothesis evidence. (Code Name: Lokum)
Informed	- Both the concepts of data and evidence are explained. - The relationship between data and evidence is explained or exemplified. - Appropriate use of scientific terminology. - Identification of data/evidence in a lesson plan*	The data I collect during the research process and its interpretation may either support or falsify our initial hypothesis. If the interpretation of the data supports our hypothesis, the data we collected becomes evidence. For example, if we hypothesize that fur color in animals affects survival chances in different environments, we can collect data by examining the survival rates of animals with different fur colors in the same environment and use the data we gather. (Code Name: Ocean)
* This criteria was evaluated during the interviews (Int1 and Int2)		

Codebook-1 was used to analyze data sources addressing the first research question, specifically the VASI questionnaire (VASI-1 and VASI-2) and interviews (Int1 and Int2). To do so, Codebook-1 was applied to analyze the VASI-1 and VASI-2 responses of five participants across all questions, including the fourth question. This

analysis was conducted to determine their initial and final levels of conceptual understanding of data/evidence at the beginning and end of the program.

3.5.2 Data and evidence enrichment framework

At the beginning and the end of the designed course, participants were required to design a lesson plan and practice teaching at their assigned implementation schools. The objective of designing a lesson plan was to evaluate the participants' incorporation of data/evidence in their lesson plans, particularly concerning scientific explanations and practices.

The design of lesson plans was implemented through teaching practice in actual classrooms. The main purpose was to explore if the design of LP's might be mirrored in the teaching practices as intended. To this end, participants' initial and final teaching practices have been explored to assess the extent to which they have demonstrated their conceptual knowledge of the data-evidence-explanation connection as outlined in their lesson plans.

Codebook-2 was created to analyze the lesson plans and teaching practices of participants. The development of the codebook commenced with analysis of all lesson plans as the initial step. Initially, the theoretical framework guided the initial coding process of LP's. These frameworks are BRH, EE for data transformations, and MEL for evidence-texts. These frameworks were visited to identify the necessary components of an evidence-based lesson plan and thus initial codes.

The BRH (Erduran & Dagher, 2014) provided a framework through its holistic perspective on epistemic practices. BRH outlines six fundamental components essential to the growth of scientific knowledge: real-world, prediction, explanation, model, data, and activities (such as experiment, observation, and

classification). These components were employed as initial codes to identify scientific practices in the participants' lesson plans.

Data is interconnected with each component of the BRH, with evidence serving as the key connection between data and explanation. To further explore the connection between data, evidence, and explanation in the context of an evidence-based lesson plan, the EE (Duschl et al., 2021) was considered. The EE addresses five significant transformations in science lessons to develop scientific explanations based on data and evidence. Each of these transformations was also employed as codes during the initial data analysis. After careful consideration of initial codes, data transformations codes were established as use of data (either first- or second-hand data), identification of variables, data organization, and the linkage between data, evidence, and explanation.

The third and final framework, the MEL, guided the analysis of evidence texts in the lesson plans. The coding process emphasized how evidence was integrated in various forms, then organized, and finally evaluated to support the construction of scientific explanations. This framework was particularly applicable to lesson plans involving an evidence-text context, focusing on evidence provided by the teacher rather than relying on students' first-hand data collection or their engagement with second-hand data.

As the initial coding process was conducted within the scope of these frameworks, additional codes emerged from the data, particularly those related to the correct use of scientific terminology in relation to data and evidence concepts. Consequently, three frameworks and the emergent codes informed the development of Codebook-2.

In addition to codes that emerged from theoretical frameworks, Codebook-2 was created through the analysis of lesson plans designed by participants from both the first and second cycles. Ten participants from the second cycle and twelve from the first cycle designed lesson plans at both the beginning and end of the program. A total of 43 lesson plans were analyzed, leading to the creation of Codebook-2.

The levels of Codebook-2 are as follows: not applicable, naive, mixed, informed, and advanced. The levels were equivalent to those in Codebook-1 regarding conceptual understanding; however, the criteria for employing data and evidence in lesson plans and teaching practices were articulated differently.

Following the completion of Codebook-2, the LP1 and LP2 of all five participants were analyzed to ascertain their levels of data and evidence integration in lesson plans to address the second research question (RQ2). Following the analysis of lesson plans, the teaching practices of participants have also been examined to address the third research question (RQ3). Table 7 displays Codebook 2. An example lesson plan coding based on Codebook-2 is presented in Appendix I.

Table 7. Codebook-2 for Integration of Data/Evidence into LPs and TPs

Level	Criteria	Code
N/A	No data or evidence utilized.	NA
Naive	1: Data and Evidence: • Data/evidence are incorporated.	1a
Mixed	2: Data, Evidence, and Context (In addition to the criteria of 1a) • Variables are identified.	2a
	• Data/evidence are organized (e.g., table, figure).	2b
	• Data/evidence is employed without being linked to a scientific explanation.	2c
	• Misuse of the terms or failure to use terms when needed (i.e., data, evidence, explanation)	2d
Informed	3: Data-Evidence-Explanation Link: (In addition to the criteria of 1a, 2a, 2b) • Data/evidence are evaluated and linked to a scientific explanation.	3a
	• Scientific terminology such as data/evidence is employed proficiently	3b
Advanced	4: Evidence-Scientific Practices Link: (In addition to the criteria of 1a, 2a, 2b, 3a, 3b) • The use of evidence is linked to scientific practices (e.g. Real-world, research question, prediction, model) with a holistic perspective.	4a
*For teaching practice, it will be assessed whether each item was effectively reflected in the implementation of the lesson.		

3.6 Researcher's positionality

The researcher, a former science teacher with considerable experience designing science learning environments for preschool through eighth grade, has worked with diverse student populations and educators across Turkey. As a graduate of the same university program as the participants, she completed her practicum and internship in

a K-12 school. She also worked in NGOs as a monitoring and evaluation specialist, broadening her understanding of educational contexts. Her background in science education and firsthand experience integrating scientific evidence into teaching inform her perspective on interpreting participants' experiences.

Currently, the researcher as a PhD candidate and practicum course instructor, she played a direct role in designing and implementing the learning environment. This dual role may have shaped her interpretations of participant engagement and learning. Additionally, her position of authority in the classroom could have influenced participants' openness during interviews and feedback sessions. This dual role underscores the importance of maintaining reflexivity to recognize and mitigate any unintended biases (Creswell, 2013). Acknowledging her strong commitment to evidence-based science lessons, she maintained reflexivity to mitigate bias. This reflection allows her to approach the data with more awareness and objectivity, while acknowledging how her perspective may shape her conclusions.

To enhance objectivity, she observed science methods and practicum courses under her advisor's guidance before the implementation. During the pilot, her advisor collaborated on course implementation, data collection, and teaching observations. Additionally, her advisor's feedback helped her reflect on her approach and maintain a balance between her dual roles. The pilot study also helped her gain experience teaching at the university level. Throughout the process, she regularly consulted her advisor, refined data collection tools, and engaged in peer debriefings to ensure credible, data-driven findings. These external perspectives allowed the researcher to scrutinize the researcher's interpretations, helping to identify any biases and refine conclusions (Nowell et al., 2017).

During data collection, she prioritized understanding participants' perspectives by fostering an open environment where they could freely express their views without judgement. Interviews were conducted to explore how preservice science teachers interpret the role of evidence in science education, allowing them to express their own understanding and reflect on their own teaching. The researcher refrained from evaluating PSTs' responses as true or false. Instead, during class discussions, she brought issues to the group's attention, encouraging peer commentary to foster shared understanding. In lesson plan feedback sessions, rather than providing direct solutions, she used reflective questions to guide PSTs in refining their designs and making their own instructional decisions.

3.7 Trustworthiness of the study

Trustworthiness in qualitative research is commonly evaluated through the four criteria outlined by Lincoln and Guba (1985). These four criteria, credibility, transferability, dependability, and confirmability ensure the rigor and reliability of qualitative research.

Credibility refers to the confidence that can be placed in the integrity of the research findings. To enhance credibility and ensure that findings are robust, triangulation was used in this study, which involved multiple data sources. For example, to understand participants' conceptual understanding of data and evidence, both the VASI questionnaire and interview responses were analyzed. Specifically, the same key question was posed in both the VASI questionnaire and the interview to explore in greater detail whether participants could distinguish between data and evidence.

Creswell (2013) emphasizes the importance of prolonged engagement in qualitative research, as it allows researchers to deepen their understanding and gather more accurate, credible data. In this study, the researcher, also the course instructor, spent time engaging with participants not only during the course but also through spontaneous conversations about their interests, future teaching goals, and views on science teaching and practicum schools. Additionally, the researcher interacted with the practicum schools and mentors of the PSTs to familiarize themselves with the conditions in which the participants would be teaching. This prolonged engagement helped refine the design over time and ensured that the research findings were rooted in real classroom contexts (Reeves & McKeeney, 2015). Understanding the practicum conditions also allowed the researcher to adjust the design trajectory. Furthermore, the researcher thoroughly reviewed the data multiple times to ensure that no details were overlooked.

Peer debriefing is another strategy used to enhance credibility and trustworthiness in qualitative research. This approach involves engaging peers or colleagues, who are not directly involved in the study, to critically review the research design, data collection methods, analysis, and interpretations. The goal of peer debriefing is to expose the researcher's assumptions, interpretations, and conclusions to external scrutiny, identifying any potential biases or gaps in reasoning. Merriam (2009) highlights peer debriefing as a crucial strategy for enhancing credibility in educational research. In this study, the researcher engaged with peers within her doctoral community as a learning group focused on design-based research. Discussions on how to interpret the findings and reviewed the methodology and analysis process. Additionally, the researcher consulted with science teachers and PhD scholars from other universities who teach practicum

courses. Their input on the research methods, analysis, data, and interpretations further helped refine the study and contributed to ensuring its credibility.

Transferability refers to the extent to which the findings of a study can be applied to other contexts while respecting the uniqueness of the original research setting (Lincoln & Guba, 1985). In design-based research (DBR), providing rich and thick descriptions is essential to support transferability. This study incorporated detailed accounts of the design process, design decisions informed by data, and participants' work, including examples from their lesson plans and interview and questionnaire responses. These thick descriptions offer a comprehensive understanding of the research context and processes, enabling other researchers or practitioners to determine whether the findings are applicable to their own educational settings. Additionally, presenting data through detailed examples—such as excerpts from participant interviews or analysis of lesson plans—ensures transparency and provides other researchers with a clear understanding of how the design guided PSTs' learning and teaching practices. By documenting these elements rigorously, this study offers insights that can inspire adaptations in similar educational research or practice.

Dependability in qualitative research refers to the consistency and reliability of the research process, ensuring that the findings are repeatable and that the study is well-documented for future reference (Lincoln & Guba, 1985). In this study, several strategies were employed to enhance dependability:

1. **Audit Trail:** A systematic approach to data collection and organization was followed, ensuring that all research processes, decisions, and materials are documented thoroughly. This audit trail allows for transparency and enables other researchers to replicate the study or reanalyze the data for alternative

insights (Bowen, 2009). All stages of the design process and data analysis are available for scrutiny and implementation in future studies.

2. Code-Recode Strategy:

- Given the longitudinal nature of the study, with a pilot and two iterations, a substantial amount of data was collected and analyzed over an extended period. During this process, the researcher revisited the same data multiple times, applying a code-recode strategy to refine interpretations.
- As the researcher engaged with different types of data—such as interviews, lesson plans, and observation notes—new perspectives emerged, leading to iterative revisions of the codebooks. Peer debriefing, expert consultations, and feedback from conference presentations further contributed to refining the analysis. This aligns with Nowell et al. (2017), who emphasize the importance of revisiting data to enhance dependability through evolving insights.

3. Inter-Observer Consistency: During two out of the ten teaching practices, data collection was conducted with other expert researchers to compare field notes for consistency. This step was particularly critical since recordings were not permitted, and observational field notes served as the primary data source. By comparing notes with experts, the researcher ensured that observations were interpreted consistently and that potential biases were minimized. This practice aligns with Creswell (2013), who advocates for collaborative validation of qualitative data. Finally, all ten teaching practices was conducted with other science teachers as well and their observations were discussed.

Confirmability in qualitative research ensures that the findings are shaped by the participants' experiences and data rather than the researcher's personal biases or motivations (Lincoln & Guba, 1985). To establish confirmability, reflexivity is carefully considered which addresses the researcher's critical examination of how her background, experiences, and assumptions may influence the research process and outcomes (Berger, 2015; Creswell 2013).

- The researcher, a former science teacher with extensive experience in designing science learning environments from preschool to eighth grade and working with diverse student demographics, acknowledges how her professional background may shape her perspectives.
- Additionally, her roles as a specialist in monitoring and evaluation for NGOs provided a foundation for understanding diverse educational contexts across Turkey.
- As an instructor of the practicum course and a researcher of the doctoral study, the researcher's dual role might have influenced how she facilitated PSTs' learning and interpreted their teaching practices. This dual role underscores the importance of maintaining reflexivity to recognize and mitigate any unintended biases (Creswell, 2013).

Detailed records of research decisions, data collection, and analysis processes were maintained to ensure that findings are traceable and grounded in the data (audit trail). This approach allows external researchers to follow the decision-making processes and confirm that the interpretations align with the data (Bowen, 2009). Triangulation of data through multiple data sources was used to ensure that the findings were corroborated and not overly reliant on a single perspective. For instance, the use of interviews, lesson plans, and observations ensured a more holistic understanding of

PSTs' experiences and minimized the potential for researcher bias. Peer debriefings were conducted through regular discussions with peers and experts in the field allowed for external perspectives to scrutinize the researcher's interpretations, helping to identify any biases and refine conclusions. These debriefings ensured that the findings remained data-driven and credible (Nowell et al., 2017). By employing these strategies, the study aimed to ensure that its findings reflect the participants' experiences and not the researcher's predispositions. While the researcher's background enriched her understanding of the field, maintaining reflexivity and engaging in critical discussions ensured the integrity and confirmability of the research.

CHAPTER 4

DESIGN OF THE LEARNING ENVIRONMENT

In this chapter, design principles guiding the design of the practicum course and their embodiments to the course will be explained. Then, implementation of the designed course for the pilot study, first cycle, and second cycle will be presented in terms of main themes and topics of the course.

During the design of learning environments, design principles provide guidelines to combine theory and practice (Bakker, 2019). Sociocultural learning theory, teacher learning, and science education frameworks informed the design principles guiding the current study. These design principles were scaffolding, reflection, and providing meaningful learning context. By integrating these principles, the study aims to create an inclusive environment that fosters the development of preservice science teachers.

4.1 Design principle 1: Provide scaffolding

Scaffolding refers to the guided assistance provided by an expert to enhance the learner's performance on a task that the learner cannot achieve alone (Reiser & Tabak, 2014). Several researchers considered the link between scaffolding and sociocultural learning theory (Palinar, 1998; Tabak, 2004, Reiser & Tabak, 2014). This link can be established through cultural tools to improve learning. Cultural tools help to build a shared understanding between the learner and the expert towards the common goals of the task and accomplishing these goals.

The use of evidence to produce arguments and generate scientific explanations is a challenging task that does not occur instantly when people are

asked to produce a strong argument; therefore, it necessitates scaffolding (Andriessen & Baker, 2014; Osborne et al., 2004). Jimenez-Alexandre (2007) highlighted that to promote such epistemic practices the design principles of a learning environment should support scaffolding their development. In learning environments, facilitators can scaffold learning of epistemic practices by setting a model and guiding the inquiry, encouraging learners to provide evidence to justify a claim, developing and providing criteria for evidence to construct and evaluate scientific explanations and arguments (i.e., critical examination of evidence), translating epistemic goals, and encouraging learners' reflection (Jimenez-Alexandre, 2007).

In a learning environment, scaffolding can be embedded in various elements, including teacher strategies, activities, artifacts, and computational tools (Reiser & Tabak, 2014). Models, visuals, representations, hints, and prompts can be utilized as scaffolding tools (Quintana et al., 2004). Reiser (2004) proposed structuring tasks for scaffolding to reduce the learner's cognitive load by maintaining a clear direction. An example of structuring can be the provision of specific criteria (Ryu & Sandoval, 2012). According to McNeill et al. (2006), providing written instructional support to students strengthened their scientific explanations and facilitated the integration of necessary elements of a scientific explanation. Research suggests that the use of software-realized scaffoldings has been helpful in scaffolding students' construction and evaluation of scientific explanations (Sandoval & Reiser, 2004), and use of evidence (Sandoval & Millwood, 2007; Sandoval & Reiser, 2004).

Scaffolding has also been useful in preservice science teacher education to link claims with evidence, support arguments with evidence (Zemba-Saul et al., 2002), promote scientific language norms in terms of talking and writing science, and to negotiate meaning of scientific concepts (Avraamidou & Zemba Saul, 2010;

Zemba-Saul, 2009). Table 8 presents embodiments of scaffolding in the designed practicum course.

Table 8. Embodiments of the First Design Principle in the Course Design

Embodiment of Design Principle-1	Pilot	First Cycle	Second Cycle
Provide scaffolding			
1. Benzene Ring Heuristics (BRH)			
– used to gain a holistic perspective of scientific practices and their interconnections to data/evidence.	✓	✓	✓
2. Evidence-Explanation Continuum (EE)			
– used to explicitly express data transformations to generate scientific explanations and to exemplify its use in teaching practices		✓	✓
3. Model-Evidence Link Diagram (MEL)			
– used as a sample of integrating evidence-texts into teaching to scaffold both for constructing evidence-based explanations and designing instructional materials.	✓	✓	✓
4. Sample Lesson Plans			
– Used to scaffold understanding and utilization of data transformations to construct evidence-based explanations and integrating various forms of scientific evidence.	✓	✓	✓
Activity-1: designed by researcher based on literature	Only physics	Physics	Physics
Activity-2: LPs prepared and implemented by previous PSTs		Biology	Biology
Activity-3: LPs designed by current participants.		chemistry	chemistry
5. Feedback on the first draft of LP2s (with peers and instructor)	✓	✓	✓
6. Facilitation of group discussion and classroom discussions	Online	In-class	In-class
7. Deliberate use of language of science (e.g., scientific practice terminology) by the instructor:			
– Scientific language is deliberately used by researchers and facilitators throughout the course. Participant responses were revoiced with the proper language of science when necessary to scaffold both for their understanding and their use of scientific language in their teaching.	✓	✓	✓

4.2 Design principle 2: Facilitate reflection

Reflection is a way of gaining awareness of one's own learning progress towards a goal or a complex situation with the aim of making better decisions to proceed in new contexts in future tasks (Edelson & Reiser, 2006; Lin et al., 1999).

Sociocultural learning theory underline three important processes related to reflection (Lin et al., 1999). Firstly, reflective thinking is a process that occurs on both individual and social levels (Collins et al., 1989). Social interactions play a crucial role in reflective thinking because feedback from others and consideration of multiple perspectives enable learners to critically examine their own learning in relation to others (Lin et al., 1999). This allows learners to gain new perspectives and identify gaps in their own thinking. According to Lin et al. (1999), feedback from peers, teachers, or experts can facilitate learners' evaluation of their own performance.

Secondly, reflective thinking is a process of active learning (Ash et al., 2005) for exploring one's own learning through critical thinking that can be promoted through meaningful learning settings (Lin et al., 1999). Reflection is also a purposeful process that can be triggered by complex and problematic situations. However, it is important to explicitly frame and reframe the problem so that it becomes visible for the learners (Loughran, 2002b). Reflection is an intentional process (Lin et al., 1999) that requires learners to look back on past experiences and explore different ways to derive meaning from them. The aim is to integrate this meaning into future practice (Loughran, 2002b). Therefore, the seeds of reflective thinking are planted for learners to become lifelong learners.

Finally, reflective thinking is an attempt to understand one's own learning process (Lin et al., 1999). It is associated with planning, monitoring learning

progress, evaluating learning experiences to modify when necessary to gain new perspectives on learners' performance in various contexts (Edelson & Reiser, 2006). Reflection can occur on two levels: on the product and on the process. Although the product, such as a written lesson plan prepared by a teacher, is visible, the process of preparing it is generally more implicit and difficult to monitor (Lin et al., 1999). Therefore, the interviews included questions about PSTs' own lesson plans to facilitate reflection on their learning processes and allow for the tracking of their development.

Abell and Bryan (1997), conceptualized the science methods course based on reflection orientation to teaching science. Science teaching orientations refer to a teacher's knowledge and belief regarding the goals and purposes of science that drive the instructional decisions (Magnusson et al. 1999). Reflection orientation is described as learning to teach science is monitoring, evaluating, and refining one's existing theories (Abell & Bryan, 1997). Reflection orientation uses various contexts of learning to teach science to provide suitable conditions for reflection and learning. Reflection tools created some tensions for preservice teachers which was appreciated by the researcher. They described those tensions necessary to experience puzzling and confusion to motivate reflection which results in learning. As an example, tensions created due to video-based cases and classroom observations of preservice teachers were influential to question and make sense of the teacher's role in the classroom. The multiple contexts provided for reflection in their science methods courses were PSTs own teaching via field experiences, others' teaching via multimedia materials, on self as science learner, and on expert opinions in teaching via course materials.

The design of the current study was guided by providing multiple contexts for reflection used in guiding the reflection process. Peer feedback sessions, observation of mentor teachers' instruction, and examples of video-based teaching provided enabled to reflect on others' lesson plan and teaching that enrich their reflection context. Interviews also served to reflect on their own teaching. Table 9 presents embodiments of reflection in the designed program.

Table 9. Embodiments of the Second Design Principle in the Course Design

Embodiment of Design Principle 2	Pilot	First Cycle	Second Cycle
Facilitate Reflection			
1. Reflection on first draft of LP2s (with peers)		✓	✓
2. Interview to promote reflection on			
– PSTs' teaching practice and lesson plans	✓	✓	✓
– PSTs' learning of the role of evidence in science and science education.			
3. Reflections on sample lesson plans provided during the designed course	✓	✓	✓
– designed by instructor, previous PSTs, and current PSTs			
– MEL diagrams			
4. Reflection on samples of video-based teaching activities		✓	✓
5. Science Lesson Observation Task: PSTs' observation of mentor teachers on use of evidence and analysis of textbook:		✓	✓
– To reflect on expert teachers' teaching practices evidence in relation to the use of evidence.			revised
6. Reflection on the designed course in relation to their learning	✓	✓	✓

Science lesson observation task and sample lesson plan activity-1 are displayed in Appendix J and Appendix K, respectively.

4.3 Design principle 3: Provide meaningful learning contexts

Learning sciences discipline suggests that learning and context are inseparable (Barab, 2014). Research on teacher learning also suggests situating learning experiences of teachers in a meaningful context (Putnam & Borko, 2000; Magnusson et al., 1999). While meaningful contexts are actual classrooms, supportive contexts are environments where teachers are supported to develop their practices in line with new instructional strategies (Magnusson et al., 1999). Opportunities for preservice teachers in Turkey to gain experience in real classrooms are limited. However, they can observe classroom environments and receive guidance for lesson planning in Practice Teaching Science courses. Additionally, they have the opportunity to practice teaching two to four times in the Practice Teaching Science course during their final year. This design principle suggests two aspects.

1. Teachers should be provided with opportunities to learn new instructional strategies in supportive and meaningful contexts. For preservice teachers, critical reflection on their teaching should be encouraged, in addition to the support and feedback provided by experts as they plan lessons. (Magnusson et al., 1999).
2. Teachers should experience what they have prepared to teach to their students. (Magnusson et al., 1999). This is to say that teachers should have firsthand experience with the activities, instructional strategies, and tools they planned. For example, if a teacher aims to promote students' critical examination of evidence, they should participate in similar activities to develop this skill. In order for teachers to effectively guide their students' learning, it is important for them to

have an understanding of how their students think and develop ideas about the subject matter (Borko, 2004). Although this is closely related to the teacher's pedagogical content knowledge, their own experiences as learners of various activities and strategies can also provide valuable insights for their teaching.

Providing meaningful learning contexts promotes learners' motivation and facilitates content learning that can be utilized in future tasks. Engaging in authentic practices of the community is an effective way to provide meaningful learning context (Edelson & Reiser, 2006). The goals of learning tasks become more meaningful to learners when authentic practices are integrated into a curriculum as context (Edelson & Reiser, 2006). For example, working on socio-scientific issues provides a meaningful context for learners in science education. Providing a supportive and meaningful context for teacher candidates resulted in the development of an understanding to identify necessary aspects of argument-based instruction that was later reflected in their practice (Zemba-Saul, 2009). Table 10 presents embodiments of meaningful learning context in the designed program.

Table 10. Embodiments of the Third Design Principle in the Course Design

Embodiment of Design Principle-3	Pilot	First Cycle	Second Cycle
Situate learning experiences in meaningful contexts			
1. Science education curricular documents:			
– to highlight formal responsibilities, aims, and competencies of science teachers' duties in relation to scientific and epistemic practices.	☑	☑	☑
2. Lesson plans for science education objectives:			
– to implement in a real classroom environment	☑	☑	☑
3. Teaching practice in a real K12 classroom setting with students:			
– to situate their learning in a real-world context	☑	☑	☑
– to implement an evidence-based instruction			
– to practice appropriate scientific language.			
4. Evaluation of sample lesson plans prepared and implemented by previous and current PSTs	☑	☑	☑
5. Presentation of related research studies conducted within the Turkish context to highlight real classroom applications and their outcome.	☑	☑	☑
6. Talk and discussion with an expert science educator and/or science teacher			
– To provide a meaningful learning context on how scientific practices and scientific evidence is significant in science education, and about implementation of instructional materials in real classroom environment		☑	☑
7. Age of the Earth Activity: A video-based scientists' speech to make real-world connections on			☑
– how scientist work with evidence			
8. Science Lesson Observation Task: Observing science teaching in schools will provide authentic learning about the conditions, constraints, and necessities of a real classroom environment in relation to evidence-based teaching.		☑	☑

4.4 Conjecture map for the design of the learning environment

Sandoval (2014) proposed a representational tool known as a conjecture map, which illustrates the flow of design from high-level conjecture to desired outcomes through embodiment and mediating processes. A high-level conjecture is a theoretical assumption rooted in literature that endorses specific desired forms of learning within a particular context. Embodiment refers to a way of expressing how high-level conjectures will be reified in terms of tools and materials, task structures, participant structures, and discursive practices. These design features support the high-level conjecture. Enactment of these embodied design features is expected to yield theoretically desired outcomes through mediating processes. Mediating processes are observable interactions and participant artifacts that are predicted to emerge as representations of how the conjecture is happening. The desired outcomes encompass both learning and design outcomes. Essentially, it represents the participants' takeaway from the design. Figure 6 illustrates the conjecture map of the current research.

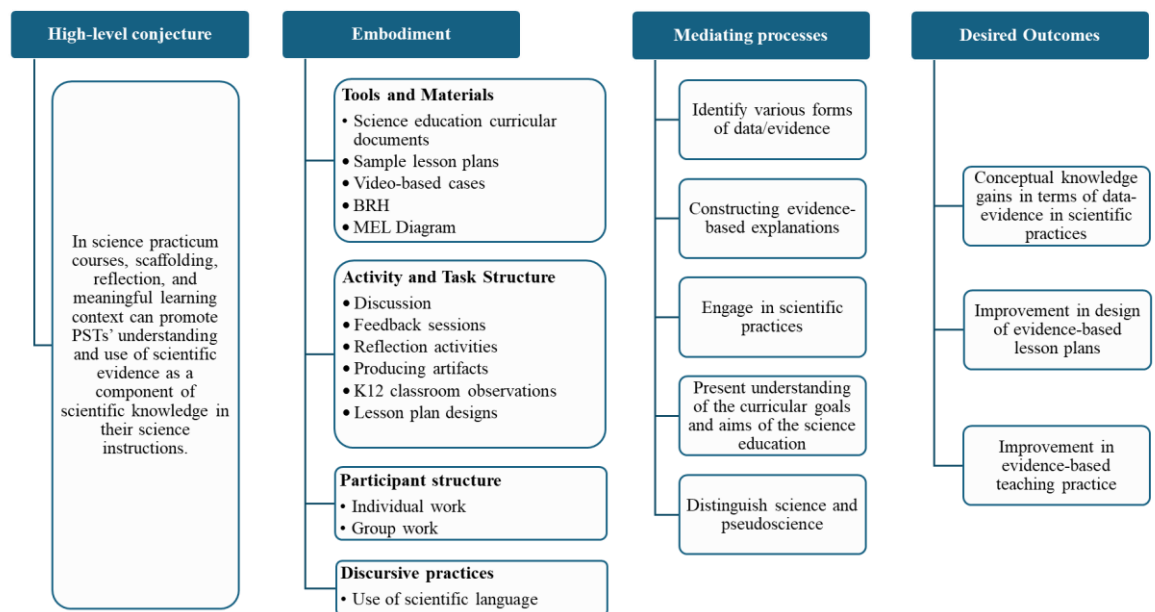


Figure 6. The conjecture map of the design

4.5 Implementation of the designed course

4.5.1 Pilot study

The pilot study was conducted with the aim of both discovering learners' needs and testing the main learning activities of the designed program. It was aimed to observe whether the PSTs' learning needs align with the relevant literature and identify the necessary support.

4.5.1.1 Design of the pilot study

Originally, the course covered five main topics, with three distributed over five weeks of in-class sessions (Figure 7). Reflection sessions were conducted at the beginning (Theme 1) and end of the course. Teaching practices in Theme 5 focused on PSTs' lesson plan design and implementation in K-12 classrooms. The first topic in Theme 2 (evidence in science) was allocated 100 minutes (one week). While most themes followed a one-week, 100-minute structure, some extended beyond a single week.

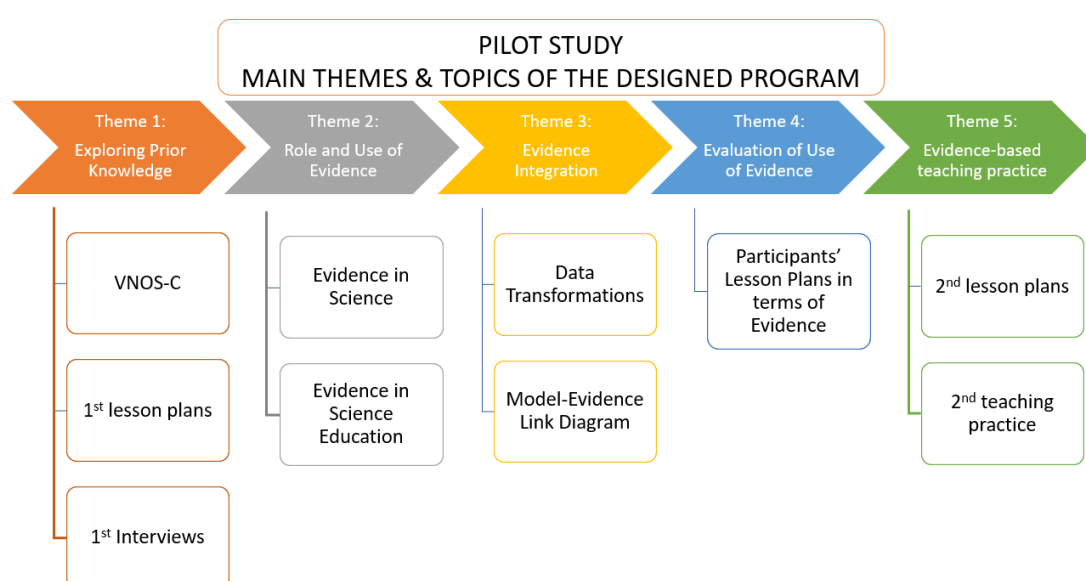


Figure 7. Main themes in the pilot study

During implementation, some themes extended beyond the intended week due to PSTs' duties in implementation schools. PSTs needed time to discuss issues from their K-12 experiences other than science lesson content and assess real-life conditions of schools. Therefore, it was not practical to dedicate the full 100-minute session solely to planned activities. Given the real-life setting, sessions were extended to the following week when necessary. As the pilot study also evaluated the duration of instructional materials, these timing adjustments were noted for first-cycle revisions.

4.5.1.2 Findings of the pilot study

The pilot study aimed to evaluate the appropriateness, effectiveness, and duration of the instructional materials. Additionally, participants' LP1, LP2, Int1, and Int2 were analyzed to assess their engagement with the program and its contribution. Two participants were selected as detailed case examples during the pilot, and the results will be presented below.

4.5.1.2.1 Case 1: Didem

The first case, Didem as her pseudo name, was selected because she demonstrated a high level of proficiency as a preservice science teacher even at the start of the program. Her first lesson plan (LP1) incorporated scientific practices, and in her initial interview (Int1), she displayed a solid conceptual understanding of data and evidence alongside other scientific practices. She also successfully identified data and evidence in her LP1. However, her LP1 and Int1 lacked a holistic perspective on scientific practices, as the necessary connections for the advancement of scientific knowledge were not fully established. This case was chosen to assess whether the

course activities were sufficiently designed to support high-achieving PSTs in enhancing their lesson planning and teaching practices.

Didem's first lesson plan (LP1) involved an experiment with a structured data collection process. The experiment had a clear purpose, and a well-defined scientific question was established. The objectives and instructions were explicitly stated, guiding students to identify variables before conducting the experiment. Following the experiment, a scientific explanation was provided. While the lesson plan incorporated scientific practices, it lacked a holistic perspective to establish essential connections among them.

For instance, the engagement phase of LP1 concluded with a scientific question about the sources of sound. However, in the exploration phase, the lesson transitioned directly into experimental procedures without explicitly linking the scientific question to the experiment as a scientific activity. Similarly, although students identified variables before the experiment, these were not further elaborated during the activity. A structured data collection table was absent, leading students to record their observations in sentence form rather than as organized data. This gap indicated that the connections between experimentation, data collection, and explanation were not fully integrated, limiting the lesson's effectiveness in highlighting the interrelationships among scientific practices.

In her LP2, Didem designed an experiment in a simulation program in which students made observations and collected data. The experiment had a clear purpose, and a well-defined scientific question was established. The data collection process was well-structured, with data systematically recorded in tables for interpretation. A scientific explanation was constructed based on the collected data.

Didem effectively used scientific language during her lesson, guiding students to recognize data as a crucial component of scientific explanations. She also facilitated a discussion on the growth of scientific knowledge and how scientists work with data to develop explanations, drawing parallels between students' work and scientists' work. During Int2, she articulated her instructional choices, explaining both what she did and why. While her LP1 evaluation was already above average, she demonstrated further progress in LP2 by making the necessary connections among scientific practices and reinforcing the relationships between data, evidence, and explanation.

4.5.1.2.2 Case 2: Luna

The second case, referred to as Luna, was selected because she initially demonstrated a lower level of proficiency as a preservice science teacher. While her LP1 included scientific practices, it did not reflect a strong conceptual understanding of data and evidence. In her Int1, she recognized some missing practices in her LP1 and TP1 but still lacked a holistic view of scientific practices. This case was chosen to evaluate whether the designed course activities were sufficient to support the learning and development of low-level PSTs in enhancing their lesson plans and teaching practices.

In Luna's LP1, students conducted an experiment with guided observations and predictions using data collection tables. Although she explained the scientific purpose during the engagement phase, the lesson plan lacked a clear scientific question to lead the inquiry. Data collection was included in the plan, but it was not explicitly identified as data, nor was the process framed as data collection for students. The conclusion was presented as a scientific explanation, but its basis in

data and evidence was unclear. Instead, she emphasized the role of observations in forming explanations but did not sufficiently address the connection between observation, data, and explanation. While LP1 incorporated key scientific practices, it lacked a holistic perspective and needed further development.

In her initial draft of LP2, Luna designed a lesson incorporating direct instruction, using a text from the Ministry of National Education (MoNE) coursebook and a presentation for students. During feedback sessions, she expressed uncertainty about how to incorporate an experiment to collect data. After discussions, she revised her plan to include a scientific question, an experiment, data collection, and a scientific explanation. Initially, she suggested identifying variables after the experiment but after discussions, she adjusted the plan to identify variables of the scientific question before the experiment. This revision emphasized scientific processes and connections to scientific practices.

During implementation, she adhered to the revised plan, using appropriate scientific language and making connections between the activity, predictions, data, and explanations. Two key moments occurred: first, she followed her initial idea of identifying variables after the experiment, as discussed earlier. The second involved an unexpected measurement error during the experiment. Ideally, it would be preferable to explain this error scientifically, discussing why scientists conduct multiple experiments. However, her initial reaction was to rely on content knowledge to explain how the experiment should have worked. She later attempted to explain the error through a real-life analogy, which was more appropriate.

In Int2, Luna reflected on this experience, explaining that stress prevented her from thinking of a scientific explanation at that moment. Her LP1 included scientific practices, but she was unaware of some, such as analyzing and interpreting data,

resulting in a lack of a holistic view of scientific practices. In her LP2, she became more aware of how to connect these practices, but when faced with unexpected challenges in teaching practice, she relied on content knowledge and text resources instead of making scientific connections with students.

Findings indicate that although the evaluation of two cases showed improvement in their understanding and teaching practices related to scientific practices, issues with the use of data and evidence remained, particularly in Luna's case.

4.5.1.2.3 Program evaluation

Participants expressed that they benefited from most of the activities during the pilot study. The findings from the program evaluation interview (Int3) to improve the design are summarized as below:

1. Participants recommended a face-to-face learning environment, as they found Zoom problematic for group discussions, particularly when videos were turned off by other participants.
2. Participants suggested limiting small groups to a maximum of three members to enhance communication and ensure an equal workload.
3. Participants preferred an activity-based structure with user-friendly tools for activities, such as concept mapping.
4. Participants noted that the activities were beneficial in helping them understand the connections between scientific practices and gain a holistic perspective.
5. Participants appreciated the sample activities, including sample lesson plans and Model-Evidence Link diagrams (MEL).

6. Participants acknowledged that although they were familiar with many terms, creating a concept map proved both challenging and valuable for evaluating connections between fundamental scientific concepts.
7. Participants valued the instructor's use of scientific terminology, particularly regarding data and evidence, noting that it helped them incorporate this language into their own lessons.

4.5.1.2.4 Design decisions for the first cycle

Based on these findings, several design adjustments were made to improve the program for the first cycle. These adjustments aimed to promote the incorporation of evidence in lesson plans and teaching practices. The design revisions made in the first cycle are as follows:

1. Use of BRH: The BRH activity was applied as an instructional scaffold throughout the first cycle to support participants' understanding of scientific practices. It was used to identify scientific practices and data evidence in sample lesson plans, observe mentor teachers' practices, and help participants reflect on their LP2s during interviews, facilitating their understanding of connections between scientific practices, data, and evidence in lesson plans and teaching.
2. MEL Activity: In the pilot study, the MEL activity was divided into two sessions due to time constraints. For the first cycle, a full 100-minute session was planned. Expert speakers were involved to enhance the activity's relevance to scientific practices and their classroom implementation. This session emphasized developing teaching materials using evidence texts and integrating evidence into lesson plans and teaching.

3. Evidence-Explanation Continuum (EE): A new scaffold was added to the first cycle to help participants understand data transformations, which illustrate how data is used in forming scientific explanations. The evidence-explanation continuum was incorporated into sample lesson plan activities to aid in analysis of lesson plans and integrating first-hand and second-hand data into lessons.

4. Sample Lesson Plan Activity-1: Initially limited to physics, this activity was expanded to include biology and chemistry. These subjects were chosen based on participant concerns about how to integrate evidence in different subject areas.

The lesson plans were analyzed through the lens of the BRH and EE to help scaffold participants' use of evidence in their teaching. The order of this activity and the MOK activity was switched to begin with a familiar structure, followed by the introduction of new design structures.

5. Sample Lesson Plan Activity-2: This activity used previous PSTs lesson plans as samples to provide authentic examples. These lesson plans demonstrated that the integration of evidence is achievable under conditions similar to those participants face. During the pilot study, participants had requested additional examples of lesson plans, which informed the inclusion of this activity.

6. Reliability of Resources: This topic was introduced in the first cycle to address participants' reliance on authoritative sources when selecting materials for lesson plans. the reliability of resources and evidence and its impact on scientific knowledge were included to help participants critically evaluate sources and integrate reliable evidence into their teaching.

7. Scientific Activities: This topic was added to the design to address misconceptions and limited understanding of scientific activities. Video-based

case studies demonstrating evidence integration to lessons were used to provide meaningful learning contexts.

8. Mentor Teacher's Instruction and Textbook: This activity was added in the first cycle to encourage participants to observe and reflect on mentor teachers' practices, as well as evaluating MEB textbooks. It aimed to foster critical thinking about the integration of evidence in teaching through the analysis of mentor teachers' use of data and evidence. It also aimed to reflect on the MEB textbook by examining the use of data and evidence in providing evidence-based explanations. Both mentor teachers' practices and the MEB textbook were included in the design to provide a meaningful learning context, as classroom teaching and textbooks are fundamental to teachers.

9. Duration of activities: Based on field notes and participants' requests, activity durations were adjusted in the design. Discussions during activities and the need to address practicum-related issues extended the planned activity times, prompting adjustments to ensure that activities were manageable within the allocated time frame.

4.5.2 The first cycle

The first cycle aimed to implement learning activities to achieve specific learning outcomes. These outcomes focused on preservice science teachers' (PSTs') understanding of evidence as a key component of scientific practices, fostering their ability to design evidence-based lesson plans, and apply evidence-based teaching practices. In Fall 2022, the first cycle of the study was designed and implemented as 14 weeks. Main themes and topics of the first cycle are presented in Figure 8.

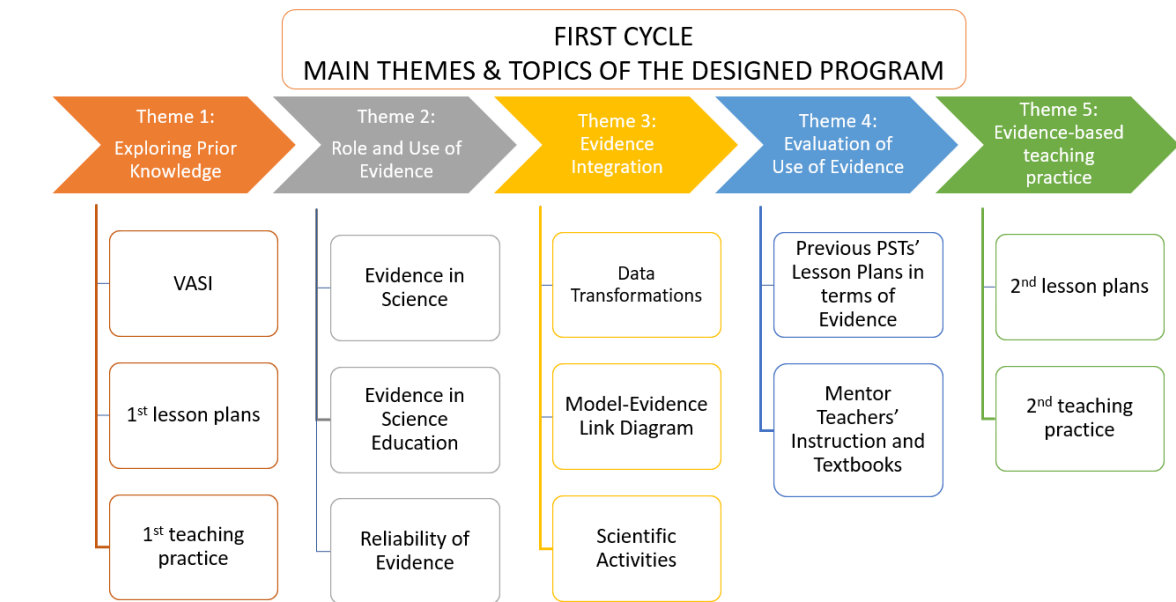


Figure 8. Main themes and topics of the 1st cycle

PSTs produced several artifacts during the first cycle of the designed practicum course. These artifacts are listed and briefly explained in Table 11.

Table 11. Artifacts Produced in the 1st Cycle

Artifacts	Type of activity	Themes	Description
LP1	Individual product	Theme-1	Participants prepared lesson plans for MEB objectives to implement in real classroom settings.
Concept Map Activity	Group work	Theme-2	Participants identified and showed connections of scientific terms in science that represent their understanding
Sample lesson plan activity-1	Group work	Theme-3	Participants analyzed three sample lesson plans based on the components of, scientific practices in BRH, and data transformations
MEL Activity	Group work	Theme-3	Participants evaluate given evidence to support and refute two models on the use of nuclear power plants.
Reflection and feedback session	In pairs	Theme-3	Participants analyzed their partner's first lesson plans and provided feedback to improve their design.
Sample lesson plan activity-2	Group work	Theme-3	Participants analyzed two sample lesson plans designed and implemented by other PSTs. (with respect to BRH, scientific practices, and evidence-explanation continuum)
Science Lesson Observation Task	Individual product	Theme-4	PST's observation report on use of evidence-based explanations
LP2	Individual product Collaboration with peers & instructor	Theme-5	Participants prepared their second lesson plans and implemented in real classroom settings

4.5.3 The second cycle

In Spring 2023, the 2nd cycle of the study was designed and implemented from March to June 2023 for 14 weeks. Main themes and topics of the designed program are displayed in Figure 9. Details of the designed program are summarized in terms of themes, purposes, and activities in Appendix L.

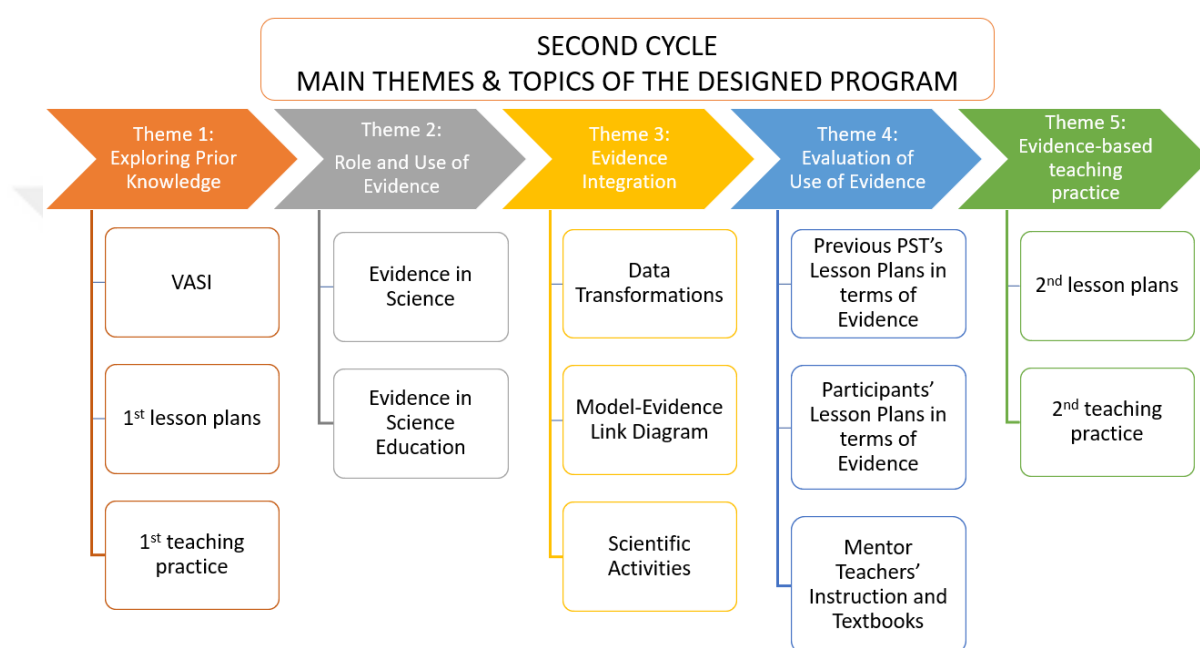


Figure 9. Main themes and topics of the 2nd cycle

Artifacts produced by PSTs in the second cycle are listed and briefly explained in Table 12.

Table 12. Artifacts Produced in the 2nd Cycle

Artifacts	Type of activity	Themes	Description
First Lesson Plans	Individual product	Theme1	Participants prepared lesson plans for MEB objectives to implement in real classroom settings.
Concept Map Activity	Group work	Theme2	Participants identified and showed connections of scientific terms in science that represent their understanding
Reflection	Individual	Theme2	Participants analyzed their first lesson plans based on Benzene Ring Heuristics.
Sample lesson plan activity-1	Group work	Theme3	Participants analyzed two sample lesson plans based on the components of BRH, scientific practices, and data transformations
MEL Diagram activity	Group work	Theme3	Participants evaluate given evidence to support and refute two models on the use of nuclear power plants.
Sample lesson plan activity-2	Group work	Theme3	Participants analyzed three sample lesson plans designed and implemented by other PSTs. (with respect to BRH, scientific practices, and evidence-explanation continuum)
Science Lesson Observation Task	Individual product	Theme4	PST's observation report on use of evidence-based explanations
Final Lesson Plans	Individual product Collaboration with peers & instructor	Theme5	Participants prepared their second lesson plans and implemented in real classroom settings

CHAPTER 5

RESULTS

In this chapter, the findings of the four research questions will be addressed. The first three research questions address the participants' conceptual understanding, lesson plans, and teaching practices in terms of data/evidence and evidence-based explanations. The last question explores how PSTs evaluate the designed course in relation to their learning.

5.1 Conceptual understanding of data/evidence

- RQ1: In what ways is PSTs' understanding of scientific evidence shaped during the designed practicum course?

The first research question (RQ1) focuses on participants' conceptual understanding of scientific data/evidence and how their understandings evolved during their engagement with the designed course. The responses from VASI-1, VASI-2, Int1, and Int2 were analyzed using Codebook-1 (see Table 6).

The overall results of the data analysis indicate that all participants began the course with a mixed level of understanding and progressed to an informed level upon completing the course activities. A detailed review of data from different sources helped identify challenges in their understanding. The results of the VASI questionnaire, as one of the key data sources for addressing RQ1, are presented in Table 13.

Table 13. Participants' Conceptual Understanding Levels in VASI-1 and VASI-2

Participants	VASI-1	VASI-2
Pınar	Informed	Informed
Meyra	Informed	Informed
Ada	Informed	Informed
Serpil	Naive	Informed
Derya	Informed	Informed

Based on the VASI-1 and VASI-2 responses, four participants exhibited an informed level of conceptual understanding of data/evidence at both the start and end of the program. An informed level of understanding involves connecting the concepts of data and evidence to scientific explanations. Participants demonstrated their understanding by using correct scientific terminology without any misuse or incorrect terms. The following responses are examples of informed level expressions:

Pınar: Yes, they [data and evidence] are different. Data are the concrete/abstract results we have, and therefore they do not have the characteristic of proving something. These data are examined, organized, and interpreted by scientists to form evidence. In a table listing the heights of students who play basketball, those heights form our data. If the height of the players is related to how many years they have been playing basketball and those data are collected, the evidence at the end of the study will have numerical value in the height-basketball relationship. (VASI-1, Informed)

Derya: They are different from each other. For data to become evidence, it must be used within a context. For example, while the brain model on its own only represents data, in the context of 'the locations of different parts of the brain,' this model (the data it represents) serves as evidence. (VASI-2, Informed)

Although Serpil demonstrated a naïve level in her VASI-1 responses, she showed an informed level of understanding in her VASI-2 by the end of the program. In the VASI-1, Serpil explained the concept of data but misinterpreted evidence, viewing it as supporting data rather than the scientific explanation. She also failed to establish

the necessary connection between data and evidence. Since she explained only the concept of data, her understanding level was categorized as naïve.

Serpil: Data is the result of a measurement or the explanation of an observation and can be obtained without the purpose of supporting another piece of data, whereas the purpose of evidence is to support/prove another data. (VASI-1, Naïve)

In her VASI-2, Serpil demonstrated an informed level of understanding by clearly explaining the two concepts and their relationship, as well as providing an example. Since she used scientific terminology proficiently, her understanding was classified as informed.

Serpil: Evidence is obtained by presenting data in a specific context. For example, the germination of seeds in the dark is a piece of data. (VASI-2, Informed)

Furthermore, Serpil provided an example to clarify these concepts.

Serpil: These data can be collected to provide evidence that light is not necessary for germination. (VASI-2)

In addition to the VASI analysis, Int1 and Int2 were also analyzed using Codebook-1.

While the interviews included questions similar to those in VASI, one question was identical. Additionally, participants were asked to identify data/evidence in their lesson plans. This additional question revealed differences in participants' conceptual understanding of data/evidence compared to the VASI. The participants' understanding levels of data/evidence based on interviews are presented in Table 14.

Table 14. Participants' Conceptual Understanding Levels in Int1 and Int2

Participants	Int1	Int2
Pınar	Mixed	Informed
Meyra	Mixed	Informed
Ada	Mixed	Informed
Serpil	Mixed	Informed
Derya	Mixed	Informed

Int1 revealed that four participants (Pınar, Meyra, Ada, Derya) demonstrated a mixed level of understanding, despite being classified as informed in the VASI-1 results.

One participant (Serpil) exhibited a mixed level of understanding, despite her responses in VASI-1 being at the naïve level.

These four participants highlighted the necessity of the context to express the interconnections of data, evidence, and scientific explanations with appropriate scientific terminology.

Meyra: I think they are different from each other. For example, in the elaboration section of my lesson plan, I provided this data, where I indicated the amounts of gases in the atmosphere. This is a data point, a numerical data point. But when I gave this to them to explain why the sky is blue, it became evidence for them. So, I provided it within the context. That's why I think it's different. (Int1)

Ada: Data are generally things that are meaningless on their own. Whether numerical, verbal, visual, or even auditory in nature. In this way, they are things that have no meaning on their own. Within a certain context, a scientific explanation based on this data would become an evidence-based explanation. (Int2)

Additionally, they have provided an example to explain these concepts.

Ada: For example, let's say a data table related to speed and acceleration is provided. An experiment or an observation is being conducted. In that observation, the speed of the object is measured first, followed by its acceleration, and these numerical data are written and recorded in the data table. But these numerical data have no meaning on their own. Because they are numerical values. Later, when these are explained in a context like "if speed increases, acceleration will be like this, if acceleration increases, speed will be like that," it becomes an evidence-based scientific explanation. (Int2)

During the reflection on Int3, program evaluation interview, Ada expressed how the program contributed to her learning about data and evidence.

Ada: I learned why data and evidence should be used. I learned what data and evidence are. I really didn't know this. I mean, if you had asked me, I couldn't have said it in the first interview anyway. Later, I learned how we could integrate it into lesson plans through both your presentations and the example lesson plans you provided. (Int3)

Pınar also reflected in Int3 that seeing several examples enhanced her understanding of data, evidence, and scientific practices.

Pınar: ...in examples of evidence and data [examples shown in class], for instance, I learned that formulas are also models that day in that class. Because what it represents is already [data]... they take the data, the data turns into a formula. You know, represented as... (Int3)

When Serpil' responses are carefully considered, it becomes clear that she showed a mixed level of understanding in her Int1. In other words, she provided examples of both data and evidence.

Serpil: The example I used in my lesson plan. When I put on two primary color filters, I see the color black appearing, this is based on data, this is the data. When I put on two primary colors, the filter shows black. This is a data for me. But, if my claim were "when I put in 2 primary colors and used 2 primary color filters, no light would pass through", and if I put in red and green filters and saw black light, that would be something. I mean, that would be evidence. It would be evidence of my claim. The evidence of my claim that no light would pass through when I wear the primary colors. (Int1)

However, due to the misuse of terms in her explanation, her understanding was classified as mixed level. This misuse of terminology was similar to the phrase she used in her VASI-1.

Serpil: Evidence. So, it seems to me like the verification of data, and that's why it seems important. (Int1)

In her Int2, Serpil provided clear and concise expressions for both data and evidence which indicates their relationship tied to scientific explanation.

Serpil: When creating a scientific explanation, something is put forth based on the data. A scientific explanation is made with the help of data. Evidence also supports these scientific explanations. Data is collected to form evidence, and we can then provide a scientific explanation based on this evidence. (Int2)

Furthermore, Serpil provided specific examples for both data and evidence in a given context.

Serpil: ...the data is not tied to any context. Let me give an example from my own lesson. For example, let's consider the occurrence of germination in a dark environment. The occurrence of germination is data even in a dark

environment. It is also evidence that light is not effective in germination. (Int2)

During the program evaluation interview (Int3), Serpil reflected on her learning process. She expressed that seeing several examples of data and evidence within the activities of Theme-1 was a crucial learning experience for her understanding of data and evidence.

Serpil: There was that slide where you showed us data examples, evidence examples. ...You know, it shows the change over the years, and there is evidence of that, etc. ...These are things that have photographs. ...Because that's how my mind works. I learn when I see evidence of something. (Int)

In summary, except for Serpil, the other four participants demonstrated an informed level of understanding in VASI-1. Given that they were senior students in their final semester and had completed the required coursework, this was an expected outcome. However, the analysis of Int1, which explored their understanding of data/evidence in depth, revealed that while they were familiar with the definitions, they struggled to identify data and evidence in a lesson plan. Ultimately, all participants completed the program with an informed conceptual understanding of data/evidence, which was essential to form a foundation for designing lesson plans and implementing them in real classroom settings.

5.2 Evidence integration in lesson plans and teaching practices

- RQ2: How does the PSTs' use of scientific evidence in their lesson plans change by the end of the designed practicum course?
- RQ3: How does the PSTs' use of scientific evidence in their teaching practices change by the end of the designed practicum course?

This section presents the results of research question 2 (RQ2) and research question 3 (RQ3) together. Participants designed and implemented two distinct lesson plans in

actual classroom environments, both at the beginning and end of the program. As their teaching practices were directly based on their own lesson plans, the findings will be presented in conjunction.

Firstly, all participants structured their lesson plans based on the 5E instructional model. The lesson plans were designed and implemented for students ranging from 5th to 8th grade. All participants developed their LP1 within the domain of physics. In LP2 designs, four participants focused on biology, while one participant centered on earth science.

Participants constructed their lesson plans prior to their teaching practices in designated schools. Accordingly, during their teaching practices, they predominantly adhered to their lesson plans. Nonetheless, the manner in which they implemented it, articulated scientific terminology, and responded to unforeseen circumstances or inquiries from students were not predetermined in their lesson plans. Therefore, understanding how the program's design elements influenced their practice is considered as a separate category. The program addressed three main issues related to learning: conceptual knowledge, lesson plan design, and teaching practice. A solid conceptual understanding of data, evidence, and explanations forms the foundation for designing an evidence-based lesson plan, which is essential for supporting evidence-based teaching practices.

Codebook-2 was utilized to analyze LP1, LP2, TP1, and TP2 of five participants, with the results presented in Table 15. When initial levels of lesson plans were considered, it can be said that 4 participants started the program at mixed-level. This is to say that they have used data/evidence in their lesson plans, considered variables, and data organization. However, their plans fail to connect data, evidence, and explanation in a way that enables students to generate evidence-

based explanations or use scientific language proficiently to enhance understanding. Only one participant's LP1 includes neither data nor evidence. Therefore, her level was categorized as N/A. Participants' LP2, on the other hand, has shown substantial evidence to categorize as advance level. This is to say that they have designed LP2's that integrate evidence-based explanations with a holistic view of scientific practices and used scientific language proficiently. In terms of implementation, participants followed their lesson plans with fidelity, which led to consistent results in their levels of incorporating data and evidence in both TP1 and TP2.

Table 15. Participants' Levels of Data/Evidence Integration in LP Design and TP

Design Integration			Implementation	
Participants	LP1	LP2	TP1	TP2
Pınar	Mixed	Advanced	Mixed	Advanced
Meyra	Mixed	Advanced	Mixed	Advanced
Ada	N/A	Advanced	N/A	Advanced
Serpil	Mixed	Advanced	Mixed	Advanced
Derya	Mixed	Advanced	Mixed	Advanced

Finally, during LP1 and TP1, only Derya explicitly used the term data, while other participants referred to it as observations, drawings, or did not use the term at all. In LP2 and TP2, all participants demonstrated proficient use of terminology when addressing data, evidence, and explanations.

5.2.1 Participants' lesson plans and teaching practices: Examples and insights

Examples of participants' lesson plans and teaching practices will be provided as evidence of their use of data/evidence. The findings of participants' lesson plans (LPs) and teaching practices (TPs) provide insight into how well they align with data collection, evidence evaluation, and evidence-based explanations in particular and the scientific practices in general. In reviewing these elements, various aspects of lesson plan design and implementation were considered, including the clarity of their objectives, the alignment of activities with the planned phases of the 5E instructional model (Engage, Explore, Explain, Elaborate, Evaluate), and the integration of scientific practices into the lesson.

In terms of LP1 and TP1, participants demonstrated similar levels of effectiveness in designing and implementing their lesson plans. While they were able to follow the structure of the lesson plan closely, including using activities to promote student engagement in investigations, they faced challenges in facilitating classroom discussions, managing time effectively, and guiding students to connect their investigations to scientific concepts. Additionally, inconsistencies were observed in participants' ability to integrate scientific terminology and facilitate evidence-based explanations in LP1 and TP1. Particularly in TP1, there was a lack of emphasis on connecting data to the overall explanation, leading to missed opportunities for reinforcing key scientific principles.

Overall, the evidence of participants' second lesson plans (LP2) and teaching practices (TP2) highlighted the importance of clear instructional objectives, pedagogical content knowledge, effective use of scientific terminology, and well-designed activities to lead evidence-based explanations to enhance students'

conceptual understanding of the topic. Areas for improvement include self-efficacy in classroom management strategies.

5.2.2 Examples of lesson plans and teaching practices

5.2.2.1 Example-1: An advance level LP and TP

Serpil: Advance level in LP2 and TP2.

General Information

Grade Level: She designed LP1 for 7th grade students.

The lesson focused on the concept of germination in biology, with the objective that "students will be able to identify and observe the factors that affect seed germination by the end of the lesson." The teacher aimed to incorporate 6 out of 8 scientific practices, including analyzing and interpreting data, constructing explanations, engaging in argument from evidence, asking questions, and obtaining and communicating information. Analyzing the lesson plan through the lens of scientific practices, all 6 practices mentioned were evident in the plan. Although the practices of planning and carrying out investigations and using mathematics and computational skills were not specifically highlighted in the lesson plan, the design of the lesson inherently involved investigation.

Flow of the lesson design:

The teacher began the lesson with engagement of the students, connecting the topic to the previous discussion on the human reproduction system, and drawing parallels to plant reproduction. She encouraged a lively discussion about the factors influencing seed germination and guided students to think critically while practicing how to design an experiment, including identifying key variables.

For the exploration phase, Serpil designed four experiments each addressing different factors (Figure 10). Students worked in groups of four using worksheets to investigate specific factors for germination, such as water, light, oxygen, and temperature. Each group made predictions about their assigned factor and identified dependent, independent, and control variables. As the experiment required long-term observation, the teacher provided QR codes for videos of pre-conducted experiments.

Group Members:	Time: 8 Minutes
Does Germination Occur at All Temperatures?	
Experiment Objective: To examine the effect of different temperatures on germination.	
Research Question: Does temperature affect germination?	
<i>Discuss these questions with your group members and answer them in detail.</i>	
Part 1: Let's Design an Experiment	
1) If you were to design an experiment to test the effect of temperature on germination, what would be the dependent, independent, and control variables? Write them in the relevant sections.	
Independent variable: Dependent variable: Control variables:	
Part 2: Let's Making a Prediction	
2) Make a prediction with your group members about the effect of temperature on germination.	
Part 3: Let's Observe	
Scan the QR code and watch the experiment video titled "Temperature".	
Based on the experiment video you watched, answer the questions.	
	

Figure 10. A segment of the exploration activity in Serpil's LP2

Students watched the videos, filled out data tables, and answered related questions, which fostered collaboration and critical thinking within the allotted time (Figure 11).

Time: 5 Minutes

3) Based on the experiment video you watched, fill in the data table below.

Mark with an "X" whether germination was observed in the containers.

	Container 1 (4°C)	Container 2 (25°C)	Container 3 (35°C)
Germination observed			
Germination not observed			

Figure 11. Example of data collection in Serpil's LP2

In the explanation phase, each group presented their findings to the class. These presentations allowed students to share evidence-based conclusions and collectively build a comprehensive understanding of the factors that affect seed germination (Figure 12).

4) Based on the data obtained from your observations, make an inference.

Support your inference with evidence. Indicate whether your inference aligns with your initial predictions.

Part 4: Let's Share Data

Fill in the table below, considering the presentations of your classmates.

	Effect on Germination Observed	Effect on Germination Not Observed
Temperature		
Light		
Water		
Oxygen		

Figure 12. A segment of the explanation part in Serpil's LP2

The teacher further elaborated on the topic by introducing the concept of dormancy and its role in seed germination through an evidence-text. A discussion followed, encouraging students to connect the experiments they had analyzed to broader scientific questions, such as the importance of collecting multiple data points to draw reliable conclusions (Figure 13).

4. Elaboration (10 min)

Students will receive worksheet which has an article section on it and questions related to it. Teacher asks “Based on the text you read, could different results have been obtained from the experiments you observed? during the classsroom discussion. Asks students to show some evidence for this question than asks “What can scientists do to obtain the most accurate results when conducting experiments on factors affecting seed germination? to whole class and discusses answers in the classroom.

Figure 13. A segment of the elaboration in Serpil’s LP2

Finally, the evaluation phase included conceptual questions designed to assess students' understanding of seed germination and the factors that influence it.

Level of LP2: Advance

Serpil employed an advanced level design in her LP2 as it incorporates data and evidence, variable identification, data organization, and evidence-based explanations.

Scientific language is consistently and appropriately applied throughout the lesson plan and worksheets, particularly in relation to data, evidence, and explanations.

Additionally, the lesson plan design offers a holistic perspective on scientific practices, with each practice interconnected and reinforcing the others.

Level of TP2: Advance

Serpil practiced teaching at an advance level her TP2. Serpil remained faithful to her lesson plan design, although she encountered time management difficulties, spending more time on the engagement phase than planned. Despite this, her teaching aligned

with LP2. She was attentive to her word choices regarding data, evidence, and explanation, emphasizing each term while explaining activities to the students. She avoided offering quick answers or definitions and made a concerted effort to facilitate classroom discussions on both variable identification and the development of evidence-based explanations.

Serpil's lesson plan level improved from LP1 (mixed) to LP2 (advance) during the designed practicum course. She reflected on her learning during the course, noting that she benefited from the sample lesson plans not only in integrating data and evidence but also in the overall structure of a lesson plan and worksheet design.

Serpil: So, as I said, in the simplest terms, in my first lesson plan, before reviewing this [Sample LP], how does it happen here, for example, the instruction-giving process here. Here, it is related to being prepared by giving instructions, asking questions, and designing worksheets. or finding variables. I used these in my classes [LP2] as well. Organizing it. These really affected me in a way. Not just in this context, but in the other one as well. For example, here [Sample LP], data was directly presented to the students as evidence related to this. They were asked to draw a conclusion from this. I tried to use these in my lesson plan. How successful I was is unknown, but I tried to use them and got help from them, as I said. Later on, during the engagement phase of LP2, I opened these up and reviewed them again anyway. (Int3)

5.2.2.2 Example-2: A mixed level LP and TP

Pınar: Mixed-level in LP1. Mixed-level in TP1

General Information:

Grade Level: She designed LP1 for fifth grade students.

Topic/Objective: Propagation of Light / Students will be able to demonstrate by drawing that the light emitted from a source travel in all directions and follows a linear path.

The topic under consideration was the propagation of light within the field of physics. She targeted to integrate six out of eight scientific practices, including asking questions, planning and carrying out investigations, analyzing and interpreting data, constructing explanations, and engaging in argument from evidence, obtaining and communicating information. However, an analysis of LP1 through the lens of scientific practices revealed that only three of these practices were evident in the plan. Although using models was not explicitly identified as a targeted scientific practice, its application could be traced within the lesson. The practice of using mathematics and computational skills was not explicitly listed as a targeted practice, although it was not absent from the lesson.

Flow of the lesson design:

The lesson begins with an engaging activity where the teacher presents a video scene from *Batman v Superman*. Although the focus was on observing how a light signal travels in a straight line, it weakens the connection to the real-world. After watching the scene, the teacher prompts students to discuss the movement of the Bat-Signal with a research question, ‘What can you say about the way Bat-Signal goes to the sky?’ However, this question was insufficient in effectively guiding the experiment designed for the scientific activity, as it fails to direct attention to identifying the variables.

Next, in the exploration phase, the teacher demonstrates light propagation using a simple setup consisting of three cardboard pieces, each with a hole, and a flashlight (Figure 14). While conducting the experiment, students are expected to observe the setup. Although the position of the holes and the direction of light serve as variables, they are not explicitly identified or categorized as dependent or independent variables.

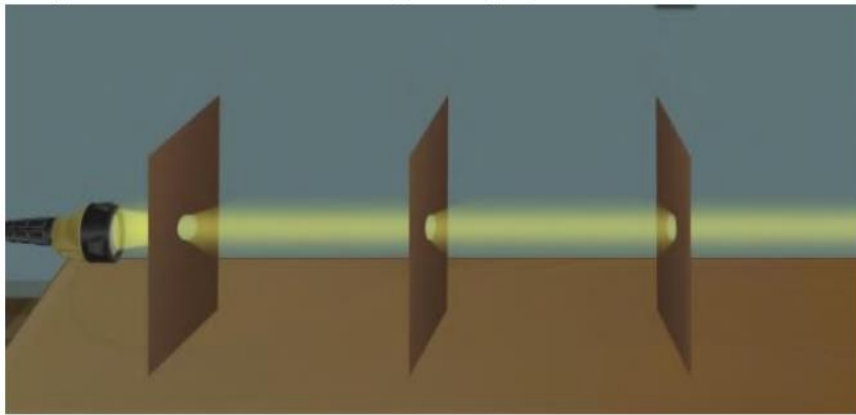


Figure 14. Illustration of the light propagation demonstration in Pinar's LP1

During the experiment, students work in pairs to answer questions in a worksheet based on the teacher's demonstration, observing how light travels through aligned and misaligned holes (Figure 15). The worksheet begins with a prediction and progresses to document observations through model drawings of what they observed after each change in the setup. While the worksheet facilitates data collection, this purpose is neither explicitly stated in LP1 nor indicated within the worksheet itself. Additionally, the collected data, represented as drawings, is not organized in tables (e.g., light passed/did not pass), which would have helped identify patterns to form evidence. Furthermore, the worksheet concludes without guiding students to connect the data to scientific explanations.

WE SHINE BRIGHTLY

Answer the following questions with your seatmate.

PART 1

1. Do you think the light rays from the flashlight will reach the large cardboard? **Yes/No** **4a-Prediction**

a) Explain why you think so in 1-2 sentences.

2. Draw a simple sketch of the setup your teacher has arranged below. **4a-Model**

Don't forget to show how the light propagates from the flashlight. **2a-Variables (holes & directions)**



1a-data

Figure 15. A segment of the worksheet for data collection in Pinar's LP1

In the explanation phase, the teacher reviews the worksheet answers with the class, yet it does not involve questions regarding analysis of data or making an evidence-based explanation. Afterwards, the teacher displays a presentation on the topic of light's linear propagation, providing textbook definitions of the topic (Figure 16). However, the presentation does not connect the collected data to the scientific explanation of light propagation as evidence. The omission of this component, coupled with the teacher's decision to offer predefined statements rather than employing data and evaluating evidence, suggests that the explanation of light propagation was devoid of data/evidence. At the end of the explanation phase, students participate by drawing light beams on the board to represent light traveling in straight lines, reinforcing the concept that light travels in straight lines.

3. Explanation (Approximately 11 minutes)

The teacher opens the worksheet on the smartboard and asks volunteer students to reply to each question one by one, after getting each correct answer and being sure that the other students agree and do not have any other answers. Then, s/he opens the presentation of the topic on the smart board (please see Appendix 4) At the end of the presentation, the teacher asks students to come to the board and draw the light beams light sources for them to show the linear direction of the light. The idea here is to see that we draw direct lines (beams) to represent light and its rectilinear propagation.

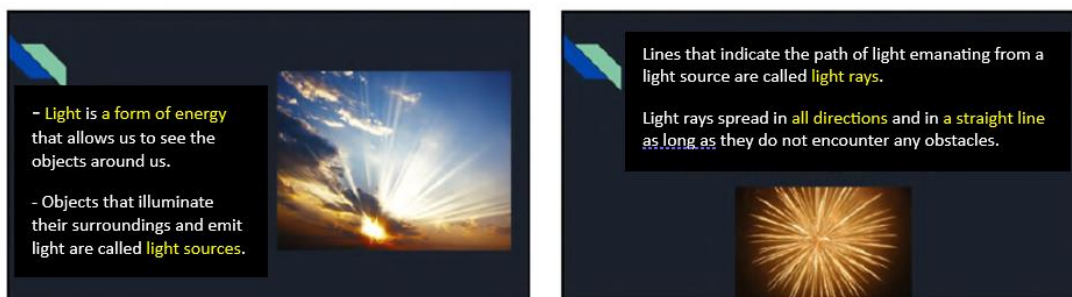


Figure 16. Example of explanation phase in Pinar's LP1

During the elaboration phase, the teacher guides a discussion about natural and artificial light sources, focusing on the Sun and stars. Students then read a text, fill in a data table on star magnitudes, and rank stars from the brightest to the faintest (Figure 17). However, this activity is misaligned with the lesson's objectives and lacks relevance to the scientific explanation of light's direct propagation, making it unsuitable as an elaboration of the core concept. The class reviews the completed table together using the smartboard, but the activity remains disconnected from the primary topic or any related scientific explanation. Although it has been coded as data, this activity does not connect to an evidence-based explanation.

WE SHINE BRIGHTLY



Read the text carefully and then complete the table on the right according to the instructions.

The **Sun**, both the heat and light source of the Earth, is a star. Like all stars, the Sun is composed of gases that constantly undergo strong reactions. As a **natural light source**, these stars produce very bright light. However, since other stars are far from Earth, we cannot perceive them as bright light sources like the Sun and consider them as part of the natural light sources of our planet.

Scientists who study celestial objects use numbers called "magnitude" to explain how bright stars appear from Earth. Bright stars have very small magnitude value. Humans can only see stars with magnitudes between 1 and 6.

➤ In the table left below, the brightness magnitudes of some stars are given. Rank the stars from brightest to dimmest by placing the brightest star in position 1.

STAR	MAGNITUDE VALUE	Brightness Ranking of the Stars
ERI	3.7	1
CENTAURI C	11.0	2
ROSS 780	10.2	3
PROCYON A	0.3	4
KAPTEYN'S STAR	8.5	5
SIRIUS B	7.2	6
POLARIS	2.0	7

Figure 17. Elaboration activity in Pinar's LP1

Finally, in the evaluation phase, students are given an exit ticket to summarize their learning by drawing a light source and explaining how it helps make objects visible. However, this task addresses content not covered during the experiment or explanation phases, further highlighting a gap in the lesson's coherence with its objectives.

Level of the lesson design: Mixed

Overall, the lesson design includes an activity involving experimentation and observation to collect data, but it lacks identification of variables, systematic data

organization, and evaluation of evidence. The lesson plan does not guide students in utilizing this data to construct evidence-based explanations, resulting in a mixed-level lesson plan. In addition, while some scientific practices are present, they do not form a cohesive and interconnected approach to effectively emphasize the intended scientific knowledge. Finally, the terms "data" and "evidence" are notably absent throughout the lesson plan, reflecting a missed opportunity to incorporate essential data-related terminology when appropriate.

Level of teaching practice: Mixed-level

Pınar began her teaching by showing a video to engage students in the lesson. She successfully demonstrated the planned experiment, and students made observations, recording their findings on their worksheets. After taking student responses to the worksheet, she made a presentation that involved statements about light. However, Pınar encountered difficulties in her teaching practice, particularly with classroom management, such as organizing students and facilitating discussions. The class was noisy, with some students continuing their own conversations, which may have been due to a lack of strong engagement or unclear instructions about what to do. Despite these challenges, she adhered to the structure of the 5E model as planned and completed her implementation about six minutes before the class session ended. This was primarily due to cutting class discussions short with direct responses and not expanding them with various examples, causing the 5E phases to conclude earlier than anticipated. Moreover, she did not address the gaps in LP1 during her implementation, such as evaluating evidence and making evidence-based explanations, which were not included in LP1.

During the teaching practice, real-world connections to the topic were limited to only the light beams from the sun and their direct route, though the lesson could

have been enriched with various daily life examples to provide evidence. She conducted the experiment as planned, asking students to share their observations and used them to explain whether light travels directly or can go around cardboard. Although the data collection process was not designed in detail in the worksheet, she attempted to use student observations to construct an evidence-based explanation through classroom discussion. However, due to a lack of content knowledge, she struggled to effectively manage the discussion, sometimes responding to students' comments incorrectly or endorsing misinterpretations. For example, when a student claimed that the light beam stopped when it hit the cardboard, she repeated the student's statement to the class and accepted it as correct, even though light does not stop but is either reflected or absorbed by opaque objects. This led to the approval of a misconception while attempting to explain the direct route of light propagation.

On the other hand, although the worksheet did not include a question or LP1 did not provide explicit guidance to establish an evidence-based explanation, she tried to facilitate a discussion based on the experiment's findings. However, while evidence was gathered, she did not make explicit reference to evidence. She did not highlight the data obtained from the experiment and observation. On the other hand, she primarily used the word "observation," asking questions such as "what do you observe?" and "did you observe light passing through the holes in the cardboard?". She also frequently phrased that "we observed light did not pass through the cardboard". After the insufficient discussion due to misguiding answers by the teacher and weak connections between data and scientific explanations, she abandoned the activity's findings and proceeded with a presentation on light propagation, without referencing the evidence students had gathered in exploration. Rather, she referenced their childhood memories of drawing in preschool:

Pınar: Do you remember you used to draw the sun as a yellow circle with linear rays around it? Well, this is the reason you drew it like that. Because light propagates directly. (TP1)

This phase of her teaching disconnected the explanation from the exploration activity and lost the interconnectedness of the scientific practices. Furthermore, she did not use the terms "data" or "evidence" at any point during the lesson. Therefore, she failed to use the necessary terminology when it was needed. For these reasons, her level of teaching practice was categorized as mixed level.

5.2.2.3 Example-3: Another advanced level LP and TP

Pınar: Advance Level LP2 and TP2

General Information:

Grade Level: She designed LP1 for 5th grade students.

Topic/Objectives: Biodiversity / "Students will be able to explain why biodiversity is important for all life on Earth" and "students will be able to discuss the factors that threaten biodiversity based on research data."

The topic covered was biodiversity within the domain of biology. Pınar aimed to incorporate 6 out of 8 scientific practices, including analyzing and interpreting data, constructing explanations, engaging in argument from evidence, asking questions, developing and using models, and applying mathematics and computational skills.

Upon reviewing the lesson plan from the perspective of scientific practices, 6 practices were clearly present. Although she did not target obtaining and communicating information or planning and carrying out investigations in LP2, these practices were still evident in her lesson plan.

Flow of the lesson plan:

The lesson begins by engaging students with a video of a credible source that strongly connects the topic to real-world issues. Biodiversity is introduced, and the reasoning behind the statement "the more biodiversity, the more secure all life on Earth" is directed for discussion. This is the main question guiding the lesson overall.

Afterward, the teacher engages students with questions about the significance of biodiversity and its decline, sharing data from the WWF's Living Planet Report 2022 and a video from TEMA Foundation. These discussions lead to the exploration activity, driven by the question: "What are the main causes of the biodiversity loss?"

During the exploration phase, students are provided with evidence-texts for 12 different species, adapted and simplified from the WWF's Wild Classroom Biodiversity Toolkit for fifth graders. These texts include various forms of evidence, such as numeric, visual, and historical data, describing the species' lives and the threats they face (Figure 18). Working in pairs, students analyze and interpret the evidence to identify challenges faced by the species and record the corresponding factors in a provided table to make a classification.

TIME TO ROLE PLAY

⇒ For the next 8 minutes of our lesson, you will take on the identity of another living being. The information you need about your new identity is provided in the text below. After reading the text, answer the question in the table below.

Monarch Butterfly

Hello, I am a Monarch Butterfly, and I have two pairs of bright orange-red wings. I can participate in a great migration event because I can travel between 2,500 and 3,000 km. As a Monarch Butterfly, I live for about four to five weeks. I rely on milkweed to lay my eggs and as a food source. However, agricultural expansion has plowed and destroyed millions of acres of milkweed, making it difficult for my species to survive. The global Monarch butterfly population, which was around 10 million in the 1980s, has declined to approximately 2 million by the end of 2021.

Monarch Butterfly



Which of the following factors put the Monarch Butterfly's survival at risk?				
Overfishing	Pollution	Dams	Agricultural expansion	Illegal hunting
Incorrect hunting	Illegal logging	Climate change	Soil degradation	Water scarcity



Figure 18. Sample segment of the worksheet in Pınar's LP2

In the explanation phase, each group presents their findings, and the class fills out a data table based on the presentations to make a classification (Figure 19). This table helps students organize their data to identify patterns related to biodiversity loss.

What kind of threats are these living things facing?										
Name	Overfishing	Pollution	Dams	Agricultural expansion	Illegal hunting	Incorrect hunting	Illegal logging	Climate change	Soil degradation	Water scarcity
1) Monarch Butterfly				X						
2) Dragon Tree								X		X
3) Sea Cedar Tree								X		
4) Franklin Tree							X	X	X	
5) Sockeye Salmon			X					X		
6) Amur Tiger							X			
7) African Elephant				X	X					
8) Black-Footed Ferret				X						
9) Black Rhinoceros										X
10) Bluefin Tuna	X				X					
11) Black Truffle Mushroom	X			X					X	
12) Gulf Sturgeon		X			X	X				

Figure 19. Data table to identify patterns related to risk factors in Pınar's LP2

During the elaboration phase, students analyze real-world data about species, exploring the relationships between these species and their life conditions (Figure

20). This activity emphasizes the importance of biodiversity and requires students to apply evidence-based explanations from earlier parts of the lesson.

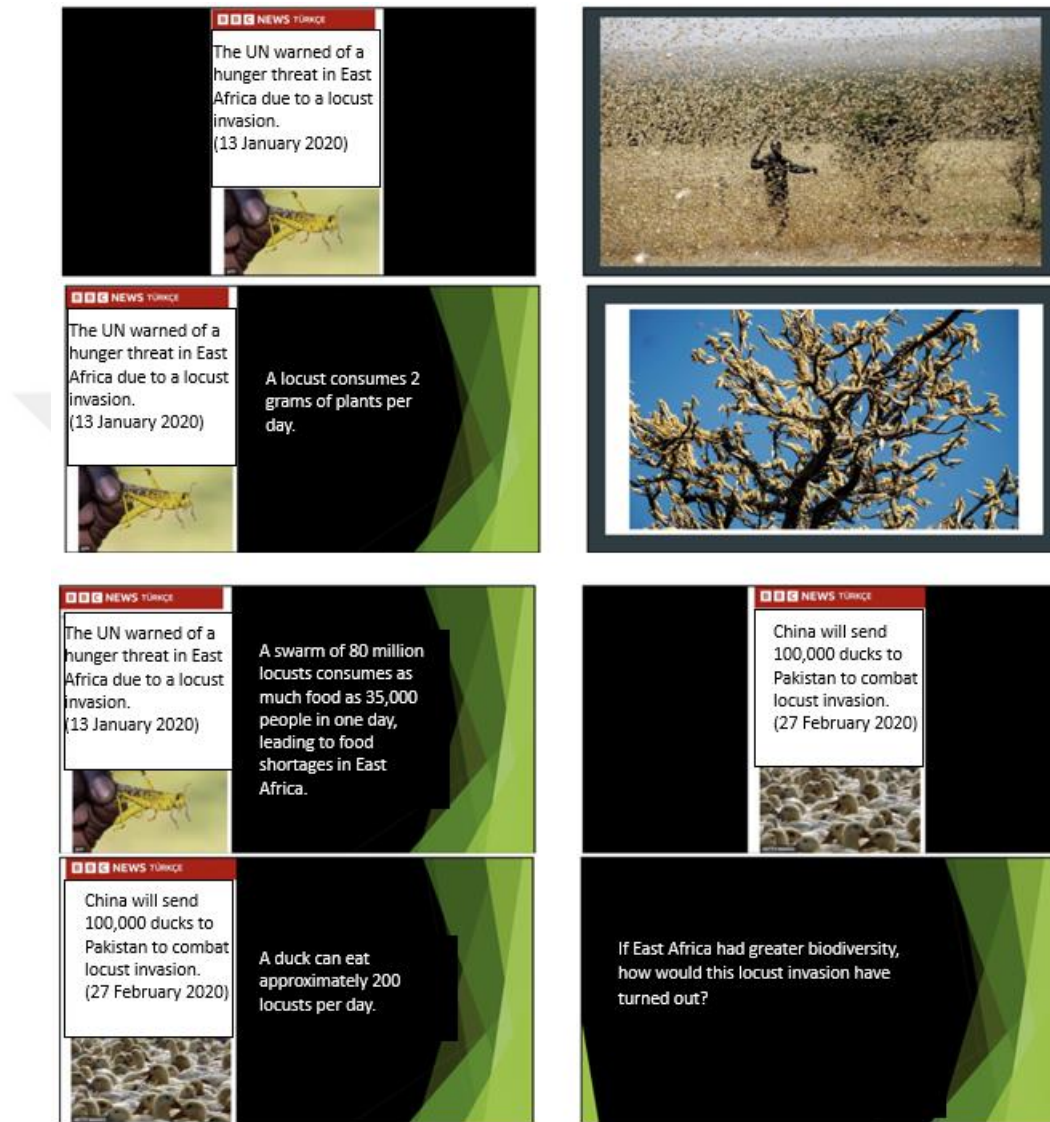


Figure 20. Elaboration in Pınar's LP2

In the evaluation phase, students are asked to explain why Einstein's statement, "the more biodiversity, the more secure all life on Earth is," makes sense, using the evidence and explanations they've gathered throughout the lesson. Reliable sources were used throughout the design to support the learning.

Level of the lesson plan: Advance

This is an advanced-level design that incorporates 12 distinct evidence texts, guided by a relevant research question. It involves data collection, data organization in tables, evidence evaluation, and the construction of evidence-based explanations. Scientific language is effectively and consistently used throughout the lesson plan and worksheets, especially in relation to data, evidence, and explanations. Furthermore, the lesson plan provides a comprehensive approach to scientific practices, with each practice interconnected and reinforcing one another. Since all positive items in the Codebook-2 can be identified in the plan, this lesson plan is classified as advance level.

Level of Teaching Practice: Advance

Pınar implemented an advanced level level during her TP2. She implemented her lesson plan with fidelity during TP2, carefully following the detailed steps outlined in the plan to accomplish tasks successfully. The lesson included rich, engaging activities and group work, and she adhered to the 5E model structure while staying within the allotted time. The strong engagement activity captured students' attention, and her clear, concise questions effectively guided class discussions. By closely monitoring group work, she facilitated the activities smoothly, demonstrating effective classroom management and a consistent flow throughout the lesson.

Real-world connections to the topic were rich and drawn from credible sources, and Pınar remained open to discussing students' comments and examples. She conducted the evidence-text activity as planned, using appropriate terminology when giving directions. When students presented their findings, she emphasized evidence-based explanations by specifically asking, "What is your evidence for that?" After all presentations and completion of the data table, she encouraged

students to identify patterns and discuss the most common factors affecting biodiversity, concluding with evidence-based explanations.

In the elaboration phase, Pinar made connections to prior activities, discussing a real-life biodiversity issue. Transitions between phases were smooth, reflecting the interconnected design and implementation of the lesson. At the end of the session, she revisited the main research question and asked students to use the evidence gathered during the lesson to respond.

Overall, the teaching practice successfully incorporated scientific practices in a cohesive manner, emphasizing the evaluation of evidence and the development of evidence-based explanations. Pinar skillfully used scientific terminology throughout the lesson, both in discourse and activities. For these reasons, the teaching practice was classified as advanced.

Evaluation of Pinar on her own learning:

Level of lesson plan and teaching practice of Pinar dramatically changed from LP1 (mixed) to LP2 (advanced) as well as the TP1 and TP2. During Int3, Pinar reflected on the progress in her lesson plans.

Pinar: Thanks to these lessons and activities, I was able to create my second lesson plan. But in my first lesson plan, I hadn't done anything like this at all. (Int3)

Additionally, she stated that learning the BRH and analyzing sample lesson plans, as embodiments of the designed program, enhanced her lesson plan design process.

Pinar: Because there is an interconnected relationship, we have already seen the connection between this BRH model and scientific practices among themselves. We saw how we use these in our lesson plans and how we can use them better thanks to this BRH model, that when we talk about activity, it doesn't just include experimentation but also observation. We saw in detail what all of these are, and as I said, I also realized that we were doing these things without being aware. In my next lesson plan [LP2], I had prepared my LP2 being more aware of this, knowing what each item in these BRH was. This BRH was very important for this reason. (Int3)

Finally, she also expressed that reflecting on her LP1 helped her realize what needs to be done to improve lesson plans. She highlighted that having strong content knowledge promoted both her design and implementation.

Pınar: Because if I want to implement an evidence-based lesson with my students, first my content knowledge needs to be sufficiently comprehensive. I realized this throughout the semester and since I self-reflected in my LP1. (Int3)

Pınar expressed how evidence-texts were instrumental by reflecting on both her own understanding and her students' understanding. She also highlighted that she realized the importance and role of PCK to design and implement evidence-based science lessons.

Pınar: After that, while preparing the evidence-texts and after implementing my lesson, I saw that when done this way, both the students' learning process and the teacher's teaching process become much more efficient and advantageous. Both sides are in a win-win situation, and that knowledge becomes more permanent for the students. Because by learning about different organisms and embodying the identity of another organism, I think they really learn well in forty-minute lesson what biodiversity is and which factors reduce the biodiversity of our world from a small text, half a page of text, a photo, a class presentation, or from their friends. This is what I have learned from this course throughout the semester. (Int3)

To sum up, she repeatedly expressed that participating in this designed course greatly enhanced her conceptual knowledge, lesson planning process, and teaching practice.

5.3 Evaluation of the designed course

- RQ4: In what ways does the designed practicum course mediate PSTs' learning to integrate scientific evidence as a crucial component of scientific practice into their teaching?

This question will be addressed in two parts: First, participants' evaluations of the program during Int3 in the 1st cycle were analyzed, and the researcher's field notes were reviewed to identify necessary revisions. The design decisions based on these findings were integrated into the 2nd cycle design. Second, participants' responses to

evaluate the program in Int3 at the end of the 2nd cycle were analyzed to identify design features that contributed to PSTs' learning in response to RQ4.

5.3.1 Design decisions for the second cycle

During the program evaluation interview (Int3), participants reported benefiting from several activities in the first cycle. Apart from the adjustments made for the duration of activities, three key design decisions for the second cycle will be explained.

5.3.1.1 Design decision-1

Science Lesson Observation Task focused on evaluation of mentor teachers' instruction and textbooks in terms of evidence use. This task was used in the first cycle, but its structure was revised for the second cycle. Field notes revealed that participants had several questions for the instructor during the task regarding how to report their findings. Additionally, the task needed clarification for PSTs' observation in implementation schools. Ayla expressed her struggle with the task as follows:

Ayla: It was an assignment that required a lot of thinking. ... We probably didn't understand the instructions with the classmates. It seemed to me that there were too many instructions. Maybe the instructions could be shortened and provided in a more concise manner.

As a result, the instructions for the task were simplified for better readability, the objectives were clarified for improved understanding, and a data collection table was added to scaffold their classroom observation. New instructions were also added to guide participants on how to report their research results.

5.3.1.2 Design decision-2

Reliability of data/evidence task involved evaluating two texts taken from newspaper to determine the role of reliability of resources and evidence in decision making

processes in real life. This was followed by a discussion on the demarcation between scientific knowledge and fallacies and the role of teachers to raise scientifically literate citizens. This topic was added for the first cycle under the Theme-2: Role and Use of Evidence.

By the end of the program, participants suggested that they already comprehended this topic during the previous course activities and the activities of this topic were more of a repetition that did not contribute much to their understanding. For example, Burcu expressed that,

Burcu: We had already been discussing how important reliable information is since the beginning of the term, and we have been debating expert opinions and expert knowledge on top of that. In those news articles [example activity], we directly said, this is as we have all seen and known. ... [in that example] when there was no reliable source, we all agreed. ... I felt like we already knew the topic [reliability].

Rather than treating this topic as a separate activity, discussions on the reliability of resources and evidence were integrated and reinforced within other design topics in the second cycle.

5.3.1.3 Design decision-3

Age of the Earth Activity involved a video presenting speech a scientist about the role of evidence in science. This activity was incorporated into the design of the 2nd cycle under the Theme-1. The main reason for using a video was that it is not always feasible to invite a scientist to speak in person due to time constraints and accessibility. The talk focused on the role and importance of evidence in the growth of scientific knowledge and how scientists work with and interpret evidence. The context used for the discussion was the determination of the age of the Earth, which the participants could easily relate to both as citizens and as science teachers. This activity was included to provide a meaningful learning context for the participants.

5.3.2 Findings of the 2nd cycle

At the end of the program, all participants took part in an interview to reflect on their learning experience and to assess the contribution of the program's design characteristics to this process. The interview questions covered three primary categories related to their learning: conceptual understanding, lesson planning, and teaching practice. These categories align with the research questions (RQ1, RQ2, and RQ3). The conceptual learning category corresponds to participants' understanding of data and evidence concepts, their interrelations, and their connection to scientific explanations as well as scientific practices. The lesson plan category focuses on guiding participants in developing their lesson plans, particularly emphasizing the use of data/evidence to design evidence-based science lessons. The teaching practice category focuses on how participants incorporate their reflections on data and evidence into their classroom instruction.

The findings will be presented in the following order. First, participants' reflections on their learning during the program will be categorized into three areas: conceptual learning, lesson planning, and teaching practice. Next, four key embodiments of the designed program will be discussed in terms of design principles, as well as their role in conceptual learning, lesson planning, and teaching practice. Afterward, participants' suggestions for improving the design will be presented. Finally, a synthesis of the findings related to the design will be provided.

5.3.2.1 Category 1: Conceptual learning

Participants evaluated their conceptual understanding of data and evidence during Int3 and identified three key challenges in their learning. These challenges relate to concepts or information that were either new, complex, or outside of their prior

understanding, making them difficult to grasp beforehand. Table 16 outlines these shared challenges, along with additional evidence supporting their responses and their interpretation.

Table 16. Key Challenges in Participants' Conceptual Learning

Key challenges in learning	Example quotations
Understanding of data, evidence, and their relationship	Meyra: I previously thought that data and evidence were completely different from each other. You know, data and evidence have separate definitions. In essence, evidence is also data. When evaluated within a context, it turns into evidence.
Appreciation of the role and importance of data and evidence	Derya: I learned about the importance of using data and evidence in scientific explanations... it is important to integrate these into our lessons and use them to support the scientific explanations in our classes. Simultaneously, it is important to have students make explanations based on data and evidence. Ada: I learned why data and evidence should be used. I learned what data and evidence are. I really didn't know this. So, if you had asked me, I couldn't have said it in the first place during our first interview.
Familiarize with a distinct type of data & evidence	Pınar: For example, at first, I only knew that data consisted of tables. So, at the beginning of this semester, when you asked me, I thought it would be tables, there would be numbers in the tables, you would use those numbers like an explanation, turning them into evidence. But I didn't know about visuals, historical data, verbal data, statistical data, I mean, I didn't know these. For me, data was just numeric data presented in tabular form. But we learned that it wasn't like that.

The first challenge focuses on participants' understanding of data, evidence, and their relationship. Participants highlighted how their understanding of the relationship between data and evidence evolved throughout the program. Meyra, for instance, initially believed that data and evidence were completely distinct concepts (Table 17). This shift in understanding reflects the participant's growing recognition that evidence is a form of data, but one that has been analyzed or interpreted within a specific context for scientific purposes. It underscores the program's effectiveness in

helping participants recognize the interconnectedness of these two concepts in scientific practices.

The second challenge is appreciation of the role and importance of data and evidence. Participants emphasized the importance of incorporating data and evidence into both scientific explanations and classroom instruction. Derya stated, “I learned about the importance of using data and evidence in scientific explanations... it is important to integrate these into our lessons and use them to support the scientific explanations in our classes.” They also highlighted the need for students to make evidence-based explanations, reflecting the program’s focus on fostering a deeper appreciation for the role of data and evidence in science education. Derya continued, “Simultaneously, it is important to have students make explanations based on data and evidence.”

The third challenge is getting familiarized with distinct types of data & evidence. Participants reflected on how the program expanded their understanding of what constitutes data and evidence beyond traditional forms. Pinar shared, “...I didn't know about visuals, historical data, verbal data, statistical data... For me, data was just numeric data presented in tabular form. But we learned that it wasn't like that.” Pinar described how her experience helped her realize that evidence can take many forms, from visuals to historical data, and that these are just as valid as numeric data in scientific contexts.

5.3.2.2 Category 2: Lesson planning

The analysis explored whether understanding the role and significance of data and evidence in science and science education enhanced participants' lesson design

process. The results indicate four key challenges that participants benefited from the design in their lesson planning, displayed in Table 17.

Table 17. Key Challenges Encountered by Participants in Lesson Planning

Key challenges in LP design	Example quotations
Data- and evidence-driven LPs	Derya: ...we know that we need data and evidence for the formation of scientific knowledge. However, we need to reflect this importance in the lesson as well. Because we want to involve the students in this process as well. As a result, I can say that this course transformed the process of designing my LPs. ... designed an LP2 that prioritizes data and evidence. Compared to my LP1, LP2 was far more centered on data and evidence, and I aimed for the students to formulate evidence-based explanations. Ada: Later, I learned how to integrate it into lesson plans both through your presentations and the example lesson plans you provided.
Informed decisions to incorporate evidence into LPs	Serpil: I started to include data and evidence. I started preparing the lesson plan with this as the focal point. ...for instance, I prefer to use first-hand data more frequently. Meyra: I constantly think about how to integrate (data and evidence), and how to guide students to answer a research question.
Evidence-texts integration in LPs	Pinar: This is what I learned from this course throughout the semester: how to write, create, and prepare an Evidence Text, how to make evidence-based science lesson plans, and we saw the examples one by one in class. Thanks to these lessons and activities, I was able to create my LP2. But in my LP1, I hadn't done anything like this at all.
Structure and coherence of LP	Ada: In fact, at the beginning, when I was making my LP1, I thought it was a very difficult thing to create a perfect lesson plan. ... I would always get confused even while doing these things. But after learning this, I realized that when I actually based the entire lesson plan on data and evidence, everything flowed together. I could easily manage the flow and identify where there were gaps to address. I think it's very useful for that reason.

The first key challenge was designing data- and evidence-driven LPs. The results indicated that all participants concurred that embracing this perspective enhanced

their lesson plans by making them more data- and evidence-driven. This was evident in Derya's expressions (Table 17). This illustrates how the participant's approach to lesson planning evolved by prioritizing data and evidence, aiming to provide a more robust and evidence-based learning experience for students.

The second key challenge focused on making informed decisions to incorporate evidence into LPs. The results indicate that participants' preference for using data evolved in response to the knowledge they gained. As Serpil stated: "I started to include data and evidence. I started preparing the lesson plan with this as the focal point. ...for instance, I prefer to use first-hand data more frequently." This demonstrates how Serpil's focus evolved to incorporate data more effectively into their lesson plans, with a particular emphasis on prioritizing first-hand data. This shift occurred as she gained knowledge about first- and second-hand data, enabling her to make more informed decisions about what to include.

Apart from simply incorporating data and evidence into LP2, the focus shifted to establishing the relationship between scientific practices through data and evidence, thereby emphasizing its central role. Meyra explained it as, "I constantly think about how to integrate [data and evidence], and how to guide students to answer a research question." This statement highlights the participant's ongoing effort to establish connections between data, evidence, and scientific practices, ensuring that students are actively engaged in the process of constructing knowledge through evidence-based explanations.

The third key challenge is incorporation of evidence-texts in LPs since learning to use evidence-texts came to the forefront in designing evidence-based lesson plans.

Pınar: This is what I learned from this course throughout the semester: how to write, create, and prepare an Evidence Text, how to make evidence-based

science lesson plans, and we saw the examples one by one in class. Thanks to these lessons and activities, I was able to create my LP2. But in my LP1, I hadn't done anything like this at all. (Int3)

This highlights the participant's progression in understanding and applying evidence-texts, moving from limited prior experience to successfully designing a comprehensive evidence-based lesson plan by the end of the course.

Finally, the fourth key challenge is structure and coherence of LP. This is to say that understanding data and evidence and their role in scientific practices facilitated the design of lesson plans, improving their structure and coherence. Ada expressed that;

Ada: ...after learning this, I realized that when I actually based the entire lesson plan on data and evidence, everything flowed together. I could easily manage the flow and identify where there were gaps to address. I think it's very useful for that reason. (Int3)

This illustrates how grounding lesson plans in data and evidence provided clarity and a structured approach, enabling participants to design lessons with greater ease and coherence.

5.3.2.3 Category 3: Teaching practice

The analysis explored whether understanding the role and significance of data and evidence in science and science education promoted participants' teaching practices. Participants highlighted three key challenges: Transformation towards evidence-based TP, and content knowledge, confidence as a self efficacy issue.

The results indicate that all participants concurred that embracing this perspective helped transform their TP2 into an evidence-based science lesson compared to their LP1 and TP1. For instance, Derya expressed as follows:

Derya: My teaching practice did change. Although I had asked the students to collect and analyze data in the LP1, I hadn't been able to integrate them into that process very much during TP1. In fact, I analyzed some data myself and provided them ready-made. However, in LP2, I wanted the students to

conduct their own investigation using the evidence and present an explanation based on that evidence. (Int3)

Derya continued highlighting the increase in the inquiry level of their lessons due to a shift of a student-centered approach in analyzing data and constructing evidence-based explanations. She stated that “Therefore, in my TP2, I conducted a more student-centered activity where the students used evidence and data.”

Another participant described how she began to emphasize the use of evidence in classroom discussions:

Serpil: ... I started to go to the students with this request to show evidence. I started entering the classroom with the aim of having the students prove their prepared works, the things they showed me, or use data to help them, and to make them realize they were using evidence. (Int3)

These accounts illustrate how participants' teaching practices shifted to prioritize evidence-based activities and discussions in the classroom. This progression can be attributed to the knowledge and perspective they developed through the program.

Another important issue in the category of teaching practice emerged as self-efficacy, reflected in participants' confidence in their TP2. During Int3, three participants reported that they felt an increase in their self-confidence, professional confidence, and confidence in their LP2 during their teaching practice, while two participants indicated challenges related to self-confidence. Participants exhibiting more self-confidence during TP2 expressed that this assurance is derived from their confidence in their lesson plan. Meyra stated that "When I went to the class with my LP2, I was much more confident. I wasn't overthinking everything I was going to say like in my LP1 and TP1.”

Finally, participants also expressed the influence of robust content knowledge in their teaching practices. As they put more effort into designing their lesson plan and gain content knowledge about the topic, they felt more confidence in the classroom.

Pinar: I knew that I needed to have much deeper content knowledge. I put a lot of effort to integrate that evidence and data appropriately, to the class level, the subject, and the objective. I used a lot of reliable resources. As I said, it required a lot of preparation, but I wouldn't have been able to do these things without them anyway. This is how it should be, I learned this. ... in my LP1, which I did not know anything about evidence-based science lessons or evidence texts, nothing. ... But for LP2, I was more confident because I knew so much about the topic. (Int3)

Conversely, those experiencing confidence challenges indicated a reluctance to exit the boundaries of their LP or reported difficulties in classroom management. For example, Meyra expressed that even though her lesson planning process had undergone considerable changes, her teaching practices were not greatly influenced by the program, as she lacked confidence in her role as a teacher in the classroom. She said: "...when another question comes up, I still can't continue that discussion because I want to stick to the plan. ...I think that's something that will settle with a bit of experience." She also expressed that she was not satisfied with the scientific language she used: "...it would be better if I increased the use of the words 'data' and 'evidence' when answering students' questions."

Ada, on the other hand, identified her limited classroom management skills as a possible reason for the minimal changes in her teaching throughout the program. "I don't think I was able to convey it well. Because my classroom management is very weak." She fully recognized that classroom management is a vital aspect of effective implementation and acknowledges that it is an area that improves with experience. She expressed that "I know that classroom management is a skill acquired through experience." Ada added that this might also be because they observed little instances of exemplary teaching practice to inform their implementation, despite having encountered numerous lesson plan samples to inform their LP2. "Because I did not follow the implementation process, meaning I did not observe those lesson plans during their implementation."

Ada, then, highlights how she found certain activities, such as analyzing previous PSTs' sample lesson plans, beneficial for development of her teaching practice. She explained that reviewing these samples and receiving comments about their implementation provided her with insights in terms of feasibility:

Ada: But this one changed a bit more compared to the others. ...when you showed us these lesson plans ... and you made comments on their implementation, so we got a bit of an idea. So, we can do this job, or we can't.

Based on the participants' reflections, it can be concluded that the program design effectively offered various scaffolds, such as sample lesson plans in diverse formats, to create a meaningful learning context for the participants while designing their lessons. These resources helped participants understand how to integrate data/evidence, evidence-texts, and other practices into their lesson plans. However, during teaching practice, this meaningful context was lacking. The participants did not have sufficient opportunities to observe or engage in effective teaching practices, which provided little guidance to real classroom settings. This gap highlights the importance of not only providing activities for lesson planning but also facilitating opportunities for participants to witness and practice effective teaching in action.

5.3.3 Evaluation of scaffolds in the designed course

5.3.3.1 BRH activities

The BRH served as an instructional scaffold across all themes of the designed course, aiming to holistically support the understanding of scientific practices in relation to data, evidence, and explanation, while also integrating them into lesson plans. To achieve this, the BRH was incorporated throughout the program in various ways, including:

- To understand construction of evidence-based scientific explanations with connections to BRH components.
- Analysis of curriculum materials and sample lesson plans with respect to the scientific practices represented in the BRH.

Role of BRH as a scaffold within the design is evaluated for conceptual learning and design of lesson planning process. TP was not the primary target for BRH.

All participants agreed on four key dimensions regarding how BRH and BRH-related activities supported their conceptual learning, displayed in Table 18.



Table 18. Key Dimensions Supported by BRH for Conceptual Understanding

Key Dimensions	Evidence
to conceptualize SP and interconnections	Pinar: ...we understood that scientific knowledge or a science lesson is not just based on a single item of this circle [BRH], but that they are all actually a combination and interconnected with each other. Meyra: I saw the BRH model in such detail for the first time since third grade. When we examined it in class, I realized that I hadn't fully understood it back then. In our first lesson, I noticed how interconnected and dynamic these relationships actually are. ...I also realized that this BRH model essentially represents the steps we use to construct scientific explanations. ... helps guide us toward the conclusions we reach in our explanations. It's a valuable model because, by looking at it, we can visualize aspects of scientific processes in our minds. ...But now, when I look at it, many things come to mind, and I feel like I can express so much more if asked. I feel more informed and as if I know a lot more now. That's why I left the lesson feeling like I had gained so much.
to identify the characteristics of scientific activities and classification as one of them	Meyra: ...the example of classifying living things with the button example and the discussion about classification was also very effective. Because this might also be a topic that isn't clear in one's mind when it comes to classification. In my opinion, here, realizing that the part about separating buttons with respect to colors doesn't create anything meaningful was actually an important aspect. Derya: First of all, I learned what scientific activities are in science and what kind of characteristics they need to have in order to be considered scientific activities. For example, there was a button example, and we discussed whether it was a classification or not. Yes, for example, we had decided that it was not a scientific activity here. At the same time, I learned that the classification [BRH] is a scientific activity here. I didn't know that. I thought there were only observations and experiments. Later on, for example, we discussed observation in paleontology. There, I learned how observations are made on things that exist in nature and how scientific processes are advanced from these observations.
to recognize various forms of data and evidence through interconnections of BRH	Ada: For example, when the buttons were given alone, we saw that they didn't represent anything, but when given in a certain context, they indicated evidence. I was also very surprised that the other data, such as graphs and formulas, were models. But when I think about all of these and since we could see so many examples, I was able to make comparisons. Serpil: For instance, this paleontology example, learning that there is historical evidence. These were very important to me and thinking about its existence.

The first dimension addressed in Table 18 is to conceptualize scientific practices and interconnections. The BRH model serves as an effective scaffold for helping participants conceptualize scientific practices (SP) and their interconnections. As Pinar reflects, "...we understood that scientific knowledge or a science lesson is not just based on a single item of this circle, but that they are all actually a combination and interconnected with each other." This demonstrates how the model aids in understanding that scientific knowledge is not isolated but rather a combination of interconnected elements.

Meyra also expressed that she has seen BRH in another course of third year courses before, however she did not comprehend it fully back then. "I saw the BRH model in such detail for the first time since third grade. When we examined it in class, I realized that I hadn't fully understood it back then." This may be because BRH is explored in terms of definitions of each component, examples of them, their relation, and each represent 8 scientific practices during the designed course. She expressed that

Meyra: In our first lesson, I noticed how interconnected and dynamic these relationships actually are. ...I also realized that this BRH model essentially represents the steps we use to construct scientific explanations. It actually helps guide us toward the conclusions we reach in our explanations. It's a valuable model because, by looking at it, we can visualize aspects of scientific processes in our minds.

Additionally, within the designed course BRH is provided more linked to PST's meaningful learning context (Design Principle-3). In other words, significant examples for each component from science education context, analyzing curriculum and lesson plans with respect to BRH components aligned with PST's learning goals.

Pinar: But now, when I look at it, many things come to mind, and I feel like I can express so much more if asked. I feel more informed and as if I know a lot more now. That's why I left the lesson feeling like I had gained so much.

Together, these reflections illustrate how the BRH model encourages participants to view science as a network of interrelated concepts and practices, fostering a deeper, more integrated understanding of scientific concepts and their application.

The second dimension is focused on identifying the characteristics of scientific activities and classification as one of them. This reflects participants' understanding of scientific activities and their characteristics, particularly how classification fits into this framework. Participants gained clarity on what constitutes a scientific activity and what doesn't, based on the examples provided during the BRH activities in the program.

Meyra reflected on the classification activity, noting how the button example helped distinguish between scientific and non-scientific classifications, which deepened her understanding of scientific processes. She highlighted that “realizing that separating buttons by color didn't create anything meaningful” was an important insight into the nature of scientific activities.

Similarly, Derya discussed her learning process regarding scientific activities, particularly classification. She expressed that she was unaware that classification could be considered a scientific activity and initially thought only observations and experiments counted. Through the BRH framework, she learned that scientific activities like classification are integral to the scientific process. “I didn't know that classification was a scientific activity here. I thought there were only observations and experiments.” She elaborated on other scientific activities stating that “...we discussed observation in paleontology. There, I learned how observations are made on things that exist in nature and how scientific processes are advanced from these observations.”

Together, these statements reflect how the program helped participants recognize and differentiate various types of scientific activities and how they work, emphasizing the significance of classification as a key scientific practice.

The third category emerged during analysis is the recognition and understanding of different forms of data and evidence through the interconnectedness provided by the BRH model. Participants were able to distinguish between various types of data and evidence and understand how they play a role in scientific practices.

Ada highlighted how the activity involving button visuals helped her recognize what counts as data and evidence in context: “When the buttons were given alone, we saw that they didn’t represent anything, but when given in a certain context, they indicated evidence.” During the BRH activity, Ada was enlightened that data can come in different forms and be used in various scientific models. Exposure to numerous examples allowed Ada to better compare and understand these forms of data. Ada expressed that;

Ada: I was also very surprised that the other data, such as graphs and formulas, were models. But when I think about all of these and since we could see so many examples, I was able to make comparisons. I believe I can both make comparisons and understand them better.

Serpil’s reflection on the paleontology example emphasized the value of understanding historical evidence. “...learning that there is historical evidence. These were very important to me and thinking about its existence.” This illustrates how the BRH model helped participants recognize the significance of different forms of evidence.

Together, these insights suggest that the BRH model activity, by highlighting various types of data and evidence, helped participants broaden their understanding

and make connections between these different forms in the context of scientific practices.

In summary, according to participants' perceptions, they benefited from BRH activities in developing a clear and practical understanding of scientific practices and their interconnections. These activities were also highlighted as a great help to recognize classification as a key scientific activity and to identify essential characteristics of scientific practices. Finally, the examples provided during BRH activities were viewed as a strong scaffold that promote participants' understanding of the relationships between data and other BRH elements, thereby enhancing their learning.

Additionally, three key dimensions identified through which participants perceive BRH's support in their lesson planning process (Table 19). These dimensions highlight BRH's role as a model of scientific practices, providing guidelines for designing LPs, ensuring ease of use through visual aids, and help analyze lesson plans.

Table 19. Key Dimensions Supported by BRH in Lesson Planning

Key Dimensions	Evidence from participants
Provide guidelines to design LP	Pınar: ...scientific practices often tend to be left hanging in the air. ...This BRH model is clearer to me. Here, when we talk about scientific practices, we mean “what do we want to integrate into our lesson and what do we want to use?” It is expressed more clearly for me. Derya: ... I had opened and looked at this model while preparing my LP2. Activity, real world, model, check. Items being only single words, like "real-world". ...One word was simpler and more understandable, so I think it was much easier for me to learn and apply. ...in the teaching and learning of science, I think these should be included in our courses.
Visual Aid / simplicity of the tool	Pınar: I think it was much easier for us to use ... just a single word, fitted into a visual model ... we can directly visualize it. Derya: ...for example, since it had a visual representation, when evaluating lesson plans, there was always a BRH model on the side, and we could make associations from there. ...I think it offers ease of use.
Help analyze lesson plans	Serpil: ...because this model is more compact, it definitely makes it [LP analysis] easier to use and analyze when help is taken from these. Derya: ...made things much easier both when analyzing the sample lesson plans and when evaluating my own lesson plan, as well as during the stage of designing my own lesson plan.

The first dimension describes the role of BRH to provide guideline to design LP.

Participants reflect on how the BRH model provides a clear framework for designing lesson plans (LP), particularly in terms of integrating scientific practices. The model offers a guideline for participants to understand what to include in their lesson plans and how to apply it more effectively.

Pınar emphasizes how the BRH model clarified the integration of scientific practices into lessons. She reflected on how the model made it easier to identify and incorporate elements of science teaching: “...when we talk about scientific practices,

we mean 'what do we want to integrate into our lesson and what do we want to use?' It is expressed more clearly for me". Such comments suggested that the BRH model helped participants organize their content and flow of the lesson in a more focused and structured way.

Derya discusses how the simplicity of the BRH model helped her while preparing their second lesson plan. She found that the one-word items, like "real-world" or "model," were easier to grasp and apply in their lesson plans: "I had opened and looked at this model while preparing my LP2. Activity, real world, check. ...One word was simpler and more understandable..." This indicates that the compact nature of the BRH model allowed for easier understanding and implementation of scientific practices in the classroom.

These insights suggest that the BRH model serves as a practical tool for lesson plan design, providing participants with a clear and straightforward framework to incorporate scientific practices and design activities effectively.

The second dimension is focused on the ease of use of the BRH Model. Participants emphasized how the BRH model's visual representation made it practical and user-friendly. Pinar explained, "I think it was much easier for us to use ... just a single word, fitted into a visual model ... we can directly visualize it". Derya elaborated this by highlighting visual aspect of BRH: "Since it had a visual representation ... there was always a BRH model on the side, and we would make associations from there". This underscores the model's role as a visual scaffold that simplified the evaluation and design of lesson plans, helping participants draw connections more effectively.

The third dimension focuses on the help BRH provides to analyze lesson plans. Participants' comments centered on the practical utility of the BRH model in

lesson plan analysis and design. Participants highlighted how the model's clarity and structure facilitated the process of evaluating and improving lesson plans, making it a valuable tool for both analysis and creation.

Serpil underscored that the BRH model's compactness makes it practical to use and analyze lesson plans by stating: "...because this model is more compact, it definitely makes it easier to use and analyze when help is taken from these." This suggests that the BRH model provides a streamlined approach, reducing complexity while integrating scientific practices and enabling a more efficient analysis of lesson plans.

Similarly, Derya elaborated on this aspect of BRH model which considerably eased the process of both analyzing sample lesson plans and designing her own LP (Table 19). Derya's experiences indicate that the BRH model supported both the assessment of existing lesson plans (sample LPs) and the creation of new ones by providing a clear structure to follow.

Overall, participants view the BRH model as an efficient and effective tool, facilitating the evaluation and design of lesson plans by providing a clear, structured approach.

5.2.4.2 MEL activity for evidence texts

First, the MEL serves as an instructional scaffold to help learners understand the relationship between evidence and alternative models of explanation. The goal of MEL activity is to support participants' conceptual learning in various ways, including introducing the evidence-text concept, familiarizing them with different examples of data and evidence, and clarifying their connection to scientific explanations, models, and arguments. Furthermore, the MEL activity lay the

groundwork for participants to reflect on what they have learned up to that point in terms of their understanding of the data-evidence-explanation. Four key dimensions related to the MEL Activity are displayed in Table 20.

Table 20. Key Dimensions Supported by MEL

Key Dimensions	Evidence
Integrating Evidence-Texts into Lesson Plans	Ada: In the process of preparing my LP2, it was really helpful, especially with evidence-texts and using models. It helped me form ideas in my mind, with the help of examples. Derya: ...I can even say that what I learned was very useful in the LP2 I designed. ...I saw how different types of data are used within evidence-texts and how they can be presented to students. Pinar: This was the lesson that added the most to me throughout this program... when I left the class, I could really say, 'Okay, this is how it is.' ...of course, since it builds on previous lessons step by step. ...we saw these evidence-texts ourselves and actually how feasible they are."
Exposure to new data and evidence types	Derya: The real data used here. There was an image of a person who actually had that disease. I also learned about historical data here... like the Chernobyl disaster on the map. Serpil: These were quite good examples when viewed as evidence text.
Linking theory to practice through real-life contexts	Ada: Having the expert speaker explaining the research was very effective. It showed us what it was used for and what the students saw. The expert also gave us ideas on how we could use it ourselves, which made it effective. ...That lesson was great. Serpil: Expert guest showed us the results of a real study. This was professionally beneficial because of the applicability of what we design. In our field, it's important to ensure what we plan is feasible. This demonstration confirmed that using MEL is very logical. Pinar: We all shared our opinions about the suitability of the texts. Is this text appropriate for 5th grade? Is the objective suitable for 8th grade? Some said it was suitable, others disagreed, mentioning concerns like time constraints. ... You showed us a table with the views of other experienced teachers. We saw those as well, and it was a very rich lesson that added a lot to my understanding, building on previous weeks.

In the first dimension, integrating evidence-texts into lesson plans was highlighted by participants. According to participants, the MEL activity informed them on how evidence-texts could be effectively integrated into lesson plans, offering practical strategies for their use. As participants reflected on the activity's role in their lesson planning processes, Ada remarked, "During the process of preparing my lesson plan, it was really helpful, especially with evidence-based texts and using models. It helped me form ideas in my mind, with examples." Similarly, Derya highlighted how the activity guided her in designing her LP2:

Derya: In this lesson [MEL Diagram], I actually learned a lot. I can even say that what I learned was very useful in the LP2 I designed. ... I saw how different types of data are used within evidence-texts and how they can be presented to students.

These reflections align with findings that Derya's lesson plan advanced from a mixed level in LP1 to an advanced level in LP2. This progression was marked by incorporating evidence-texts that utilized diverse forms of evidence and explicitly connected evidence to explanations to enhance students' understanding. Derya attributed much of her improvement to the MEL Diagram activity, which she felt extensively enriched her learning and contributed to the development of her LP2 design.

Additionally, participants highlighted how the activity significantly enriched their understanding, particularly because it built upon prior lessons in the program, effectively addressing gaps in their knowledge. For instance, Pınar remarked,

Pınar: This was the lesson that added the most to me throughout this program... when I left the class, I could really say, 'Okay, this is how it is.' Because it really clicked. Of course, since it builds on previous lessons step by step, but in this lesson... we saw these evidence texts ourselves and actually saw how feasible they are.

This sense of culmination indicates how layering instructional scaffolds can enhance conceptual learning. Insights of participants underscore the value of the MEL activity

in demonstrating the practical application of evidence in supporting scientific explanations.

The second dimension explains how exposure to new data and evidence types contributed to participants. As the MEL activity introduced participants to unfamiliar types of data and evidence, it aided to broaden their understanding. Derya noted the inclusion of unique and authentic examples: "The real data used here, there was an image of a person who actually had that disease. I also learned about historical data here... like the Chernobyl disaster on the map." Similarly, Serpil appreciated the relevance and quality of the examples, stating, "These were quite good examples when viewed as evidence text."

Together, these reflections illustrate how this activity not only consolidated prior knowledge but also expanded participants' understanding of diverse forms of data and evidence, reinforcing their ability to integrate these into their lessons.

The third dimension focuses on linking theory to practice through real-life contexts. The MEL activity was structured to provide participants with meaningful learning experiences by incorporating real-life implementation outcomes and expert guest. This approach aimed to bridge the gap between theory and practice, guiding participants on how to integrate evidence-texts into their lessons. By aligning the activity with the Turkish curriculum and presenting evidence from a local classroom context, the program ensured that participants could connect the activity to the conditions of their future teaching practices.

Participants appreciated the inclusion of an expert guest who shared practical insights and research findings from real classroom implementations. Pinar reflected on this, saying, "This was already one of our teachers' research study. After we completed the MEL Diagram, having expert guest come and explain this study,

...and then participating in such a discussion environment was very important for us." Similarly, Ada noted the impact of hearing from an expert:

"Having the guest explaining the research was very effective. It showed us what it was used for and what the students saw. The expert also gave us ideas on how we could use it ourselves, which made it effective. ...That lesson was great."

Serpil emphasized how this session reinforced the practicality of the activity in professional teaching contexts:

"Expert guest showed us the results of a real study. This was professionally beneficial because of the applicability of what we design. In our field, it's important to ensure what we plan is feasible. This demonstration confirmed that and made using the MEL Diagram in that session very logical."

According to Pinar, discussions on the appropriateness of the activity, along with the opinions of experienced teachers, were another important issues to consider linking theory and practice as they learn incorporation of evidence-texts into the lessons.

Pinar emphasizes the importance of considering whether the evidence-texts align with the objectives of different grade levels, such as 5th and 8th grade: "We all shared our opinions about the suitability of the texts. Is this text appropriate for 5th grade? Is the objective suitable for 8th grade? Some said it was suitable, others disagreed, mentioning concerns like time constraints." Pinar further noted that the research-based opinions of experienced teachers provided useful insights, saying, "You showed us a table with the views of other experienced teachers. We saw those as well, and it was a very rich lesson that added a lot to my understanding, building on previous weeks." Overall, this reflects how the combination of expert talk and discussions about the suitability of evidence-texts for different grade levels helped to deepen their understanding of how to incorporate evidence-texts effectively into their lesson plans.

5.3.4.3 Sample lesson plans

Sample lesson plans were mainly integrated into the design to scaffold PSTs learning on how to integrate evidence-based explanations into their lesson plans. To achieve this goal, participants analyzed sample lesson plans not only to observe exemplary integration of data/evidence, but also, to discuss and determine points of improvement. While doing this, thus, they were given an opportunity to reflect on their understanding using sample lesson plans.

Additionally, sample lesson plans were designed to situate learning experience in a meaningful context for participants as they align with science education objectives, and that they will be preparing a lesson plan at the end of the design and implementing in a classroom. Therefore, this meaningful learning context matches their reality.

Sample lesson plan activity has been integrated in three distinct ways. First, they were provided with sample lesson plans designed by the researcher based on the literature. Second, lesson plans of PSTs who had participated in the program in previous years were used. Finally, PSTs who participate in the program currently shared their lesson plans with their fellow students. In each step, relating to meaningful context has been increased. Participants were asked to share their perception on these sample lesson plan activities in relation to their learning during Int3. They identified five dimensions that sample lesson plans supported their learning. These dimensions, along with evidence quotations of participants are displayed in Table 21.

Table 21. Key Dimensions Supported by Sample Lesson Plans

Dimensions	Evidence
Three domains of science	Pinar: ...our biases were broken, such as “it's very easy for physics, but how much can it be for biology? In chemistry, maybe it can work in that lesson if there's an experiment”. Especially in biology, memorization. ...we saw that this could be integrated into every lesson with those lesson plan examples. I think it was very effective and productive to study physics, chemistry, and biology. Because we focused the most on physics throughout undergraduate education. ...I don't remember ever encountering such a lesson in microteaching in chemistry. Derya: ...a biology and a physics example, actually two extremes for us. Generally, when preparing lesson plans, for some reason, we tend to think that in physics, we can create something more data-driven, evidence-based, and inquiry-oriented. Whereas in biology, we usually think the opposite. We got to see two different examples. That's why it was a good lesson for me.
Types of data (First- and second-hand data)	Pinar: In biology and chemistry, we also saw the use of first and second-hand data, how we turned it into evidence, how we prepared a lesson plan, and how we could fit it all into 40 minutes from these three lesson plans. Derya: ...in one [sample LPs], students draw what they observe first-hand and organize the data they collect. In the other, they analyze and organize pre-collected data. These are two different methods, which made it valuable in that sense.
Examples in guiding LP design	Serpil: ...I have checked them to see how [data/evidence] was used. They had given me quite good ideas about how to use them. I think it was quite helpful. These were concrete examples showing how the application should be.
Discussion/ group work	Ada: Groupwork was very effective. By exchanging ideas, we approached the lesson plans critically. Thanks to the questions you provided, we were able to make these critiques more extensively. ...questions helped us understand the use of data/evidence by discussing with each other and seeking answers to where and what was done...
Data organization	Meyra: There was a section on organizing data for physics, chemistry, and biology. Especially even in physics, there was a separate table for sorting data from largest to smallest. ...it goes unnoticed. ...I was very surprised when I saw that [the table] was not written in order. I thought will they fill out the same thing again? I was troubled a lot to understand. Then I really liked organizing and emphasizing data. I actually noticed such details in each lesson.

The first dimension that sample lesson plans supported is exploring use of evidence in three subject matter domains, namely, biology, physics, and chemistry. Participants appreciated exploring numerous exemplary lesson plans and emphasized the benefits of exploring three science disciplines, as they broadened their perspective and enriched their learning experience. Participants expressed the contrasts between fields, particularly noting the differences between biology and physics. They underscored that in terms of chemistry and biology topics, evidence-based biology and chemistry examples have broken their prejudices.

The second dimension was learning about the types of evidence, specifically first- and second-hand data, which provided a perspective on incorporating data into the classroom environment, both with and without active data collection. In other dimensions, participants expressed that they benefited from these samples while preparing their LP2s, as they provided concrete examples for the application of data and evidence. Moreover, all participants stated that they gained value from the group discussions as they analyzed and discussed the sample lesson plans.

5.3.4.4 Feedback sessions

At the start of the program, participants independently created their LP1s. They collaborated with the instructor and their peer mate at their classroom observation school but did not receive feedback regarding scientific practices or evidence-based explanations. Instead, their LP1 was reviewed solely for its alignment with grade level and objective suitability for classroom implementation.

For LP2, participants collaborated with a peer from their observation school to exchange feedback. Initially, they drafted their LP2 individually and then met with the instructor and their paired peers to receive constructive feedback. During these

feedback sessions, discussions focused on ways to enhance their lesson plans in terms of evidence-based explanations and scientific practices. Participants revised their LP2 based on the feedback received, followed by a second round of feedback sessions. This iterative process of feedback and revision continued until the LP2 was finalized.

The feedback sessions aimed to scaffold the integration of evidence-based scientific explanations, helping participants achieve their highest potential based on their learning and knowledge. During these sessions, participants first reflected on their lesson plans and assessed their appropriateness. They then evaluated each other's plans and offered constructive feedback. Because these sessions focused specifically on participants' LP2, they provided a meaningful learning context closely tied to their current teaching reality. This alignment ensured the feedback sessions were guided by the study's three design principles, reinforcing their relevance and effectiveness. Dimensions of feedback sessions are displayed in Table 22.

Table 22. Key Dimensions Supported by Feedback Sessions

Dimensions	Evidence
Increase in confidence and motivation	Serpil: ...the feedback you gave me was constructive and clear. ...you offered suggestions rather than directing me. ...psychologically, in terms of self-confidence and professional confidence, you did it without damaging me; instead, this made me happier. ...It was a process that increased my motivation. I was even more satisfied with the result. ...It made me enter my class more confidently and securely
Peer review	Pınar: ...there were things I couldn't notice while preparing the lesson plan, but thanks to the feedback from you and Derya during those meetings, I was able to recognize them, and I improved my lesson much better...
Design of LP in terms of evidence	Meyra: ...I think receiving feedback greatly improved the use of data and evidence. ... In LP2, we focused a lot on organizing data and creating tables. That was a particular issue in my plan. ...Fixing that—essentially, not just presenting the data but also thinking about how we present it—is very important for students, in my opinion. I realized that.
Grade level appropriateness	Derya: ...When I prepare my lesson plan, as the person who creates it, I can't look at it from an outsider's perspective, and therefore, I often don't see my shortcomings or the points that are unclear. For example, I might express something in my own way, but I can't see that an outsider might not understand that expression or that it isn't clear enough. ...for example, in my LP2, I had prepared evidence-texts and I thought they were suitable for fifth-grade students. Because I was involved in it and created it myself, I thought it was understandable, clear enough, and not too much. But when an outsider said it might be exhausting for a 5 th grader, too long, or that the expressions were repetitive, I realized it too.
Guidance	Serpil: ...Not directly telling us what to do but explaining how to do it has been very helpful for me. ...it helps me trust both my plan and myself.
Accessibility to teacher	Meyra: ...It increased my motivation to work. ...Being able to get immediate feedback and make changes right away while I was still working on it was, in my opinion, extremely beautiful.

Results indicate that having feedback plays a great role in self-efficacy beliefs of participants to accomplish their teaching practices.

CHAPTER 6

DISCUSSION AND CONCLUSION

6.1 Overview of the study

This study emphasizes the importance of empowering preservice teachers' (PSTs) pedagogical content knowledge related to scientific evidence, a foundational component of scientific practices and science teaching. Drawing on sociocultural learning theory and the broader literature on teacher learning, the research aimed to design and implement a practicum course for PSTs that fosters their understanding of the role of scientific evidence in science and equips them to integrate scientific practices into their teaching. The practicum course was designed using principles of scaffolding, reflection, and meaningful learning to support PSTs in developing and implementing lesson plans enriched with evidence-based explanations as part of scientific practices.

The central aim of the current design-based research was to explore how well a designed practicum course could facilitate PSTs' ability to incorporate evidence-based explanations into their teaching practices. Specifically, the study examined how PSTs' conceptual understanding of scientific evidence evolved throughout the course, how they integrated evidence into their lesson planning, and how their application of evidence-based practices shifted in real classroom settings. Additionally, the research investigated the ways in which the practicum course itself served as a mediating factor, shaping PSTs' ability to embed evidence as a key component of scientific practices into their teaching. The design implementation involved a pilot study followed by two iterative cycles.

To address these objectives, the study employed a qualitative approach, collecting data through lesson plans, interviews, classroom observations, and the Views About Scientific Inquiry (VASI) questionnaire. Two distinct codebooks guided the analysis of conceptual learning, lesson plans, and teaching practices, while an inductive analysis provided insights into the role of the practicum course in fostering PSTs' integration of scientific evidence into teaching.

This discussion chapter interprets the findings through the lens of the aims of the study, offering an in-depth analysis of how the course influenced PSTs' development. It also situates the findings within the existing literature of teacher learning, identifies implications for science teacher education programs, and highlights areas for further research to strengthen the integration of evidence-based lessons in science education.

Below, a discussion will focus on PSTs learning, specifically examining their conceptual understanding of data and evidence, followed by an exploration of how evidence is integrated into teaching. Emerging outcomes will then be discussed to shed light on teacher education. Finally, the specific components of the designed course that contributed to PSTs' learning will be addressed, along with how these components mediated learning. These include BRH, EE, MEL Diagrams and reflection activities.

6.2 Discussion of PST learning

6.2.1 PSTs' conceptual understanding of data/evidence

PCK bridges content and pedagogical knowledge in teacher learning that focus on teachers' understanding of how to effectively present topics and address challenges to optimize student learning. (Shulman, 1987). A strong grasp of data, evidence, and

explanations forms the foundation for designing evidence-based lesson plans, which are essential for effective teaching of scientific and epistemic practices. By establishing this solid conceptual foundation, PSTs are better prepared to design and implement lessons that align with scientific practices. Central to this design is the understanding that these key concepts reflect how science works and how scientific knowledge is constructed. In other words, it underscores the importance of the nature of science in PSTs' learning, emphasizing the crucial role of evidence in the development of scientific knowledge.

The relevant literature highlights several challenges PSTs face regarding the use and integration of evidence in science lessons. For example, teachers often struggle with understanding epistemic practices (Erduran et al., 2021) and supporting students in developing evidence-based explanations (Newton et al., 1999; Sampson & Blanchard, 2012). They also experience difficulties in identifying the role of evidence in constructing scientific explanations (Beyer & Davis, 2008), tend to base science-related decisions on content knowledge rather than the evaluation of evidence (Saribas & Saka, 2018), and frequently confuse evidence with explanations (Sampson & Blanchard, 2012).

At the outset of the study, similar challenges were observed among the PSTs in the current research. Hence, the designed program's initial themes emphasized building PSTs' conceptual understanding of data, evidence, and explanations, as well as their interconnectedness within scientific practices. The study findings revealed that PSTs could define the concepts of data, evidence, and explanation both at the beginning and end of the program. However, a deeper analysis highlighted their initial struggles in applying these concepts in practice. For example, PSTs faced challenges in identifying data and evidence in lesson plans that they prepared and

determining whether they had successfully integrated these elements into their teaching. Effective implementation requires linking data and evidence to scientific explanations, yet PSTs often treated data as isolated observations or experiment outcomes without linking them to targeted explanations.

An important reason PSTs struggle to incorporate evidence into their teaching practices is the gap addressed by Mugaloglu and Doganca (2009) in preservice teacher education, which connects theory to practice. Therefore, for PSTs, planning a lesson and putting it into practice have their own challenges. By the end of the program, PSTs demonstrated significant progress towards integrating data and evidence into their teaching. In addition, they articulated both the types of data and evidence they used, along with the justifications of their choices. The findings revealed that PSTs developed an understanding of various forms of data, such as historical and visual data, and different uses of evidence, including both first-hand and second-hand data.

Additionally, a key outcome of the study was PSTs' proficiency in scientific terminology by the end of the program, which was evident in their lesson plans and teaching discourse. This progression signified advancement in both PSTs conceptual and practical understanding of data and evidence within scientific practices. Research indicates a strong correlation between conceptual understanding and the effective use of scientific language (Carrier, 2013, Glen & Dotger, 2009; Goldshmidt & Jung, 2011). In fact, the application of scientific language extends beyond merely understanding and providing definitions of concepts (Carrier, 2013).

One of the important outcomes of the pilot study on this issue guided the revision of the first and second cycles of the program to emphasize the importance of scientific language. Participants in the pilot study reported that they were most

influenced by the scientific language used by the instructor throughout the course. Since language is a powerful cultural tool (Vygotsky, 1978) for communicating knowledge, it also serves as a crucial means of reflecting the epistemology of science by establishing a shared language for scientific processes. Additionally, initial concerns regarding the participants' misuse of terminology—observed in their early lesson plans— and limited use when in fact necessary during their teaching practice highlighted the need for further focus on this issue. For example, four participants did not mention the words "data" or "evidence" during their first teaching practices. Therefore, the scaffolds that display proper use of scientific terms, such as the instructions of the sample lesson plans, the instructors' discourse during the sessions, and reflecting participants' expressions with approaches such as careful revoicing, emphasized during the course.

By the end of the program, participants showed marked improvement, demonstrating careful attention to the appropriate use of scientific terms in their lesson plans. Contrary to their first teaching practice, all participants not only used these terms correctly in their second teaching practices but also incorporated other scientific terms, such as "observation" and "experiment." This progress reflects not only their conceptual understanding of these terms but also their recognition of the importance of using a scientific discourse to promote students' epistemological understanding and the growth of scientific knowledge. Effective discourse is crucial for fostering collective sense-making of epistemic and scientific practices in the classroom, which in turn promotes student learning (Zemba-Saul, 2009).

6.2.2 PSTs' evidence integration

One of the central themes of the designed course was evidence integration, which entails the use of evidence to construct evidence-based explanations. In doing so, it supports the broader goal of fostering teachers who can effectively facilitate evidence-based lessons for their students. Considering the major changes in the national curriculum of science education in Turkey, it can be seen that evidence-based lessons are encouraged by National Ministry of Education in Turkey (MEB, 2024). In fact, the science education program begins in the third grade with the goal of encouraging students "to question the ways of obtaining scientific knowledge and to make generalizations about the characteristics of scientists" (MEB, 2024, p.18). The program directs teachers to facilitate students in constructing explanations based on data and evidence at all grade levels. Consequently, teacher training should align with such policy documents. Research suggests that the way conceptual knowledge and scientific practices are incorporated into the science lessons and reflected in science teaching plays a key role in improving student learning (Tekkumru-Kısa et al., 2015). The current study contributes to the field by providing insights into how PSTs can be empowered to integrate evidence-based explanations into their teaching. By equipping PSTs with strategies for incorporating data and evidence, the study emphasizes the importance of aligning science teacher education with curriculum policies that prioritize the development of students' practices to construct explanations based on evidence.

At the beginning of the course, PSTs were already familiar with data transformation processes, such as conducting experiments or simulations, from their prior coursework in the science education program. This familiarity was evident from an analysis of the course schedules and participants' reflections during program

evaluation interviews. Moreover, first-hand data collection through experiments and observations is widely documented in both preservice teacher education, particularly in laboratory courses (Altunova & Artun, 2020; Özer & Sarıbaşı, 2023; Özgelen et al., 2012), and in science lessons (Candrasekaran, 2014; Lehrer & Schauble, 2002).

On the other hand, despite their prior exposure to first-hand data collection, the initial lesson plans and teaching practices of participants revealed challenges in effectively incorporating evidence into their lessons. First, they had limited understanding of pedagogical strategies for evidence integration. In other words, they only use first-hand data collection (e.g., through experiments) to integrate data into their teaching. Second, if the conditions, such as topic or classroom environment, were not appropriate to collect first-hand data, they thought they cannot conduct an evidence-based lesson. For instance, participants initially entered the program with the preconceived notion that data collection was most suitable for the physics domain. These challenges were consistently observed across all iterations of the present research, beginning with the pilot.

To address the struggles of PSTs for effectively teaching evidence-based lessons, PSTs need to learn pedagogical strategies, participate in similar evidence-based activities, and cultivate a thorough understanding of scientific processes (Magnusson et al., 1999). This concept was addressed through two pedagogical approaches supported in the literature: the evidence-explanation continuum (Duschl et al., 2021; Zembal-Saul, 2009) and the use of evidence-texts (Hapgood et al., 2004; Lombardi et al., 2013, Ceyhan et al. 2019; Muğaloğlu et al., 2017). Data transformations provide valuable insights into integrating first-hand data use, variable manipulation, data collection, and its subsequent analysis and interpretation, representing a more traditional approach to incorporating evidence in lessons.

Evidence-texts facilitate the critical examination of evidence, particularly in situations where data collection is not feasible within a classroom environment. Both approaches were incorporated into the course design to guide participants in designing investigations for their lessons.

An effective way of teaching these pedagogical strategies was providing multiple sample lesson plans that exemplify different subject domains to develop PSTs understanding of evidence integration and pedagogical strategies. PSTs frequently noted that reviewing multiple examples was instrumental in their learning process, emphasizing the importance of connecting to meaningful and contextualized learning experiences. Moreover, they were particularly enthusiastic about analyzing biology lessons and were surprised by the outcomes. Evidence-texts further broadened their understanding, demonstrating that first-hand data collection is not the sole pathway to engage with epistemic practices. Through these activities, PSTs were able to challenge and ultimately overcome their prejudices, recognizing that evidence-based lessons can be effectively implemented across all science domains within a standard 40-minute class session. In fact, they have implemented their final lesson plans (LP2) in science domains such as biology and earth science, utilizing these two approaches for evidence integration.

Throughout the course, from the beginning to the end, PSTs developed a deeper understanding that constructing evidence-based lessons is not simply about conducting fun experiments and enjoying scientific activities. Rather, it is essential to recognize and reflect the epistemology of science in this process. Hands-on fun activities are often seen by PSTs as the primary goal of science lessons (Zemba-Saul, 2009). However, it is crucial to empower them to understand that the core purpose is to recognize the role of evidence in the nature of science, as this is

fundamental for scientific progress. Conducting scientific activities in lessons should aim to reflect the epistemology of science to students through integrating epistemic practices. Understanding epistemic practices and the underlying perspective is a key to fostering scientifically literate citizens who can make informed decisions on critical science-related issues.

6.2.3 Emerging outcomes for PSTs' learning: Content knowledge and self-efficacy

Although the designed program did not explicitly aim to teach science content knowledge, it emerged as an important outcome. Reflecting on their initial lesson plans (LP1), PSTs recognized gaps in their content knowledge related to their chosen topics and lesson objectives. To design their lesson plans (LP2), PSTs not only worked on evidence integration but also conducted extensive research, often delving into high school science textbooks and international resources to deepen their understanding. This enhanced content knowledge enabled them to identify various types of evidence, present it effectively to students, and confidently discuss it during teaching. This study emphasizes that content knowledge, alongside epistemic and scientific practices, is essential for developing robust pedagogical content knowledge (Osborne, 2014).

The interplay between content knowledge and evidence integration aligns with previous research (Ardac et al., 2005; Sampson & Blanchard, 2012; Simon & Maloney, 2006). For example, Sampson and Blanchard (2012) found that in-service teachers relied heavily on content knowledge rather than differentiation between evidence and explanation, underscoring that content knowledge is not adequate alone. On the other hand, Güzel et al. (2015) highlighted the value of pedagogical strategies in improving PSTs' lessons, showing that programs incorporating training

pedagogical tools such as IDEAS pack can considerably enhance pedagogical knowledge. The present study illustrates that both content knowledge and epistemic practices are essential for effective teaching, and that PSTs should be encouraged to improve their content knowledge to successfully incorporate pedagogical approaches into their courses.

Interestingly, confidence, as a self-efficacy belief, emerged as another outcome of this study, despite not being an initial target. Based on Bandura's social theory of learning (1977), outcome expectations and self efficacy expectations are two dimensions of self-efficacy (Muğaloğlu et al., 2016). Equipped with enhanced content knowledge and pedagogical strategies, PSTs reported feeling more confident in their teaching abilities, indicating that they had a self efficacy expectation to successfully implement their lessons. This increased self-efficacy expectation can also be linked to the structured reflection processes integrated into the course. Receiving constructive feedback from both the instructor and peers allowed them to identify areas for improvement before their practice, giving them time to revise and feel validated by others.

However, not all PSTs experienced strong self-efficacy. Some of them expressed feeling less confident during teaching, which they attributed to challenges with reflection-in-action. For example, they struggled with classroom management or felt inadequate to respond to unexpected questions or situations during their lessons. These challenges suggest that their ability to engage in reflection-in-action, which involves real-time adjustments and decision-making, may require further development. As PSTs acknowledge, their teaching practice will evolve with time and experience (Popp, 2021), highlighting the importance of continuous practice and growth in becoming effective, confident teachers. In essence, PSTs' expressions

reflect the challenges in their self-efficacy beliefs regarding their ability to accomplish tasks without difficulty and manage them successfully. These beliefs often influence their motivation and persistence in the face of obstacles. As a result, fostering a supportive environment that enhances their confidence can significantly influence their overall effectiveness and growth as teachers. As a result, self-efficacy belief should be taken into consideration while training PSTs to develop teaching practices.

6.3 Discussion of the design features in PST learning

6.3.1 The role of the BRH model in supporting PST learning

The BRH model was a central scaffold in the course design, contributing significantly to PSTs' learning progression. The BRH model helped PSTs understand the interconnectedness of scientific practices and emphasized the role of data and evidence in generating scientific knowledge. The findings indicate that PSTs viewed the BRH model as a valuable tool for grasping these relationships and integrating them into their teaching practices. Prior research supports the use of the BRH model in enhancing understanding of scientific practices (Saribas & Akdemir, 2020; Saribas & Ceyhan, 2015).

For instance, Saribas and Ceyhan (2015) addressed deficiencies in third-year PSTs' understanding of scientific practices by integrating the BRH model into their teaching. Their findings indicated improved conceptual understanding. Similarly, Saribas and Akdemir (2020) demonstrated the BRH model's effectiveness in helping university-level students comprehend the interconnectedness of scientific practices. However, both studies focused primarily on conceptual understanding of evidence without addressing implementation in real teaching contexts. The current study

bridges this gap, providing insights into how lesson planning and teaching practices can be enhanced by integrating conceptual understanding with practical application.

6.3.2 Evidence-explanation continuum in supporting PST learning

Duschl et al. (2021) highlight the EE continuum as a valuable pedagogical tool for curriculum development, citing Lehrer and Schauble's (2002) learning progression as an illustrative example derived from prior research. Although BRH model provides an holistic view on scientific practices, the path from data to explanation in the model remains undescribed. The five steps of data transformation between data and explanation, structured by the EE continuum, provide a guideline for PSTs as they evaluate and design their own lessons. Recent studies incorporating the final version of EE continuum in association with the 5E instructional model are limited. There is only one recent example using EE as an assessment tool to analyze student work (Eugenio-Gozalbo et al., 2022). The current research contributes to preservice science teacher education by applying the data transformation processes of the EE continuum to facilitate evidence integration in lesson planning. Participants' 40-minute lesson plans, developed using this approach, offer valuable insights into its practical application and versatility in fostering teacher learning of epistemic practices.

6.3.3 MEL diagrams in supporting PST learning

The Model-Evidence Link (MEL) Diagram is one way of integrating evidence-texts into science lessons. Originally developed as an instructional scaffold, MEL diagrams aim to facilitate conceptual change by promoting connections between evidence and explanations and encouraging critical evaluation of evidence,

especially in the context of socio-scientific issues (Lombardi et al., 2013). Previous research primarily addressed the use of MEL diagrams for students' conceptual learning (Can, 2017; Dobaria et al., 2022; Lombardi et al., 2013) or in-service teachers' professional development, focusing on instruction materials for critical thinking skills (Ceyhan et al., 2019). However, studies focusing on PSTs learning with MEL diagrams remain limited. For instance, Saribas and Saka (2018) investigated third-year PSTs' understanding of subject matter and evaluation skills using MEL diagrams. They found that while PSTs successfully created appropriate model-evidence links, they struggled with critically examining evidence and its relationships. Yet, their study investigated only conceptual understanding and epistemic practices of PSTs. The current research contributes to this body of knowledge by using MEL diagrams in two novel ways. First, MEL diagrams were employed to enhance conceptual understanding of evidence, rather than solely focusing on subject-matter knowledge. Second, they were utilized as instructional materials to facilitate PSTs' evidence integration into lesson planning and teaching practices, thereby highlighting and promoting epistemic practices.

Findings suggest that participants viewed the MEL diagram as a new tool for integrating evidence into lessons, providing solid examples to follow. Others expressed that it helped them learn about new types of data. Importantly, the MEL diagram activity fostered meaningful learning by situating these practices within real-world contexts. For instance, participants were presented with findings from Ceyhan et al. (2019), which highlighted experienced teachers' views on MEL diagrams as useful instructional tools despite concerns about time constraints in classroom settings. This helped PSTs validate their own analyses of the MEL diagram's utility while addressing practical concerns about its implementation.

To further address PSTs' apprehensions, the MEL diagram activity was supplemented with examples of successful real-world applications. For instance, Can (2017) demonstrated that MEL diagrams could be effectively implemented with seventh-grade students in two 40-minute class sessions, alleviating concerns about time limitations. Can's (2017) study also showed significant improvements in students' conceptual understanding of nuclear energy compared to a control group taught through traditional lectures. Drawing parallels between these research findings and their own 40-minute teaching practice conditions, PSTs were able to evaluate and selectively integrate MEL diagram components into their lessons (LP2s and TP2s) by the end of the course. Therefore, this study contributes to the existing literature on preservice science teacher education by offering insights into use of materials to promote epistemic practices in their lessons through evidence integration.

6.3.4 Reflection to support PST learning

The Higher Education Institution in Turkey (YÖK, 2018) identifies reflection as a key component of practicum courses. However, reflection often requires facilitation, as PSTs may not inherently recognize the need to monitor and reflect on their teaching and learning, nor do they always know how to engage in reflective practices effectively (Edelson & Reiser, 2006)

At the beginning of the program, PSTs engaged in reflective interview sessions upon completion of their initial teaching practices. These interview sessions included questions designed to facilitate reflection on their lesson plans and teaching practices. These sessions, along with discussions during the course that revisited their lessons as relevant topics arose, fostered reflection-on-action. This reflective process

likely contributed to their realization that their initial content knowledge and understanding of scientific and epistemic practices were insufficient for designing effective lessons. Participants frequently expressed that they became aware of key issues through the program, supporting this perspective. Reflection on action, which occurs after teaching, is categorized as one of the three types of teaching reflection (Schön, 1987).

Furthermore, reflection-for-action was emphasized during sessions where PSTs reviewed and discussed their second lesson plans before implementation. They reflected on their own plans, analyzed their peers' plans, and received feedback from the instructor. These activities were purposefully integrated into the practicum course design, aligning with Abell and Bryan's (1997) findings that providing multiple contexts for reflection fosters PSTs' learning. In addition, PSTs analyzed various examples of lesson plans, including those designed by experts, previous PSTs, and their peers, specifically focusing on evidence integration and evaluation. These structured reflection activities, increased PSTs' awareness of their teaching goals and strategies. This, in turn, contributed to their development of PCK and bolstered their self-efficacy beliefs.

6.4 Limitations of the study

The data analysis for the second cycle involved five participants enrolled in a practicum course at a public university. While the teaching practice guidelines for practicum courses apply to all PSTs across universities in Turkey, the findings are specific to one highly regarded university. As such, generalizing the results is challenging. However, the findings could provide valuable insights for future research, particularly if participant demographics are carefully considered.

The study faced two key time constraints. First, the teaching practices had to align with the implementation school's timeline, necessitating an accelerated schedule for lesson planning and feedback sessions. Second, the doctoral study of the researcher was subject to a six-year completion requirement, limiting the scope of data analysis and presentation to a subset of the extensive data collected. During the research, the pilot study was conducted online due to pandemic conditions. For instance, transitioning between online platforms and face-to-face lessons introduced unique timing challenges for course activities.

Additionally, the researcher also served as the instructor of the course, assuming a dual role that required balancing the objectives of the research with the educational needs of the PSTs. This dual responsibility introduced a layer of complexity, as the researcher had to ensure the study's integrity while prioritizing the participants' professional development. Also, the practicum course inherently adds additional responsibilities for PSTs to fulfill in their practicum schools. On the other hand, although it was repeatedly emphasized at the beginning and throughout the course that their performances or opinions related to the research would not impact their grades, it remains uncertain whether they fully overcame concerns about grading, given the inherent nature of being students in a university setting.

Finally, the current research focused solely on PSTs and the faculty of the practicum course, without incorporating mentor teachers as another dimension. Consequently, the experiences participants gained from their practicum schools and mentor teachers were neither closely monitored nor analyzed in detail, leaving these aspects uncertain. Additionally, the nature of communication and relationships between PSTs and their mentor teachers remains unknown.

6.5 Suggestions for future studies

This study can be enhanced in both student learning and teacher learning directions. First, integrating third-year science methods courses prior to practicum courses would be an option to prepare PSTs by equipping them with more detailed methods for designing and implementing science lessons. This way, they can learn designing lessons with evidence integration approaches earlier than their practicum courses and have the opportunity to practice it four times in their senior year. Second, the preservice science teacher education program could be extended to the first year of in-service teaching. While PSTs gain valuable experience through their practicum, they are not yet the primary teachers responsible for the classroom curriculum and student learning outcomes. Therefore, their experiences are limited to one teaching practice. Transitioning to full-time teaching introduces new challenges, and extending the study to support PSTs during this critical period could further enhance their professional development. Future research could also explore the implementation of a series of 40-minute lessons, each focusing on a specific course objective and incorporating data transformation processes along with in-depth epistemological discussions about the nature of scientific knowledge. This sequential approach could be evaluated to determine whether it promotes a deeper and more comprehensive understanding of the nature of science, scientific practices, and the role of evidence in student learning.

Exploring the contribution of evidence-based lessons on student learning could provide valuable insights. Such research could illuminate not only the ways students engage with and benefit from evidence-based science lessons but also inform the design of preservice science teacher education programs to better promote these practices.

For the design component, meaningful learning during teaching practice could be improved by incorporating video-based examples of real classroom teaching. These examples would provide practical insights to strengthen PSTs' understanding of evidence-based scientific explanations. Additionally, incorporating mentor teachers as collaborators in practicum courses could add a valuable dimension to the study. Collaboration with experienced mentors is recommended to empower PSTs and enhance their teaching practices through shared expertise and constructive feedback.

Finally, components of the designed course could also be selected and incorporated separately into the relevant science education program courses at universities, depending on the specific needs of the program.

APPENDIX A

ETHICAL APPROVAL FROM BOĞAZİÇİ UNIVERSITY

FOR THE PILOT STUDY

Evrak Tarih ve Sayısı: 10.04.2022-61403

T.C.
BOĞAZİÇİ ÜNİVERSİTESİ
SOSYAL VE BEŞERİ BİLİMLER YÜKSEK LİSANS VE DOKTORA TEZLERİ ETİK İNCELEME
KOMİSYONU
TOPLANTI KARAR TUTANAĞI

Toplantı Sayısı : 30
Toplantı Tarihi : 07.04.2022
Toplantı Saati : 10:00
Toplantı Yeri : Zoom Sanal Toplantı
Bulunanlar : Prof. Dr. Ebru Kaya, Dr. Öğr. Üyesi Yasemin Sohtorik İlkmen
Bulunmayanlar :

Zeynep Kaymaz
Öğrenme Bilimleri

Sayın Araştırmacı,
"Designing a Preservice Science Teacher Course to Enrich Use of Evidence in their Teaching Practices" başlıklı projeniz ile ilgili olarak yaptığımız SBB-EAK 2022/33 sayılı başvuru komisyonumuz tarafından 7 Nisan 2022 tarihli toplantıda incelenmiş ve projenizin ilk kısmı uygun bulunmuştur.

Bu karar tüm üyelerin toplantıya çevrimiçi olarak katılımı ve oybirliği ile alınmıştır. COVID-19 önlemleri kapsamında kurul üyelerinden ıslak imza alınmadığı için bu onay mektubu üye ve raportör olarak Yasemin Sohtorik İlkmen tarafından bütün üyeler adına e-imzalanmıştır.

Saygılarımızla, bilgilerinizi rica ederiz.

Dr. Öğr. Üyesi Yasemin
SOHTORİK İLKMEN
ÜYE

e-imzalıdır
Dr. Öğr. Üyesi Yasemin Sohtorik
İlkmen
Öğretim Üyesi
Raportör

SOBETİK 30.07.04.2022

Bu belge, güvenli elektronik imza ile imzalanmıştır.

APPENDIX B

ETHICAL APPROVAL FROM BOĞAZİÇİ UNIVERSITY

FOR THE MAIN RESEARCH

Evrak Tarih ve Sayısı: 04.10.2022-90837

T.C.
BOĞAZİÇİ ÜNİVERSİTESİ
SOSYAL VE BEŞERİ BİLİMLER YÜKSEK LİSANS VE DOKTORA TEZLERİ ETİK İNCELEME
KOMİSYONU
TOPLANTI KARAR TUTANAĞI

Toplantı Sayısı : 34
Toplantı Tarihi : 28.09.2022
Toplantı Saati : 16:00
Toplantı Yeri : Zoom Sanal Toplantı
Bulunanlar : Prof. Dr. Feyza Çorapçı, Doç. Dr. Arhan S. Ertan, Doç. Dr. Senem Yıldız, Dr. Öğr. Üyesi
Yasemin Sohtorik İlkmen, Dr. Öğr. Üyesi Ayşegül Metindoğan
Bulunmayanlar : Dr. Öğr. Üyesi Harun Muratoğulları

Zeynep Kaymaz
Öğrenme Bilimleri
Sayın Araştırmacı,

"Designing a Preservice Science Teacher Course to Enrich Use of Evidence in their Teaching Practices" başlıklı projenizin ikinci kısmı ile ilgili olarak yaptığımız SBB-EAK 2022/33 sayılı başvuru komisyonumuz tarafından 28 Eylül 2022 tarihli toplantıda incelenmiş ve uygun bulunmuştur.

Bu karar üyelerin toplantıya çevrimiçi olarak katılımı ve oy birliği ile alınmıştır. Onay mektubu üye ve raportör olarak Yasemin Sohtorik İlkmen tarafından toplantıya katılan bütün üyeler adına e-imzalanmıştır.

Saygılarımızla, bilgilerinizi rica ederiz.

Dr. Öğr. Üyesi Yasemin
SOHTORİK İLKMEN
ÜYE

e-imzalıdır
Dr. Öğr. Üyesi Yasemin Sohtorik
İlkmen
Öğretim Üyesi
Raportör

SOBETİK 34 28.09.2022

Bu belge, güvenli elektronik imza ile imzalanmıştır.

APPENDIX C

DEMOGRAPHIC INFORMATION FORM

Kod İsim:

Tarih:

1. Adınız Soyadınız:
2. Çalışmada kullanmak istediğiniz kod isim:
3. Doğum tarihiniz:
4. Mezun olduğunuz lisenin adı:
5. Öğretmen eğitimi aldığınız üniversitenin adı:
6. Bölümünüzün adı:
7. Uygulama okulunuzun adı:
8. Uygulama okulundaki mentor öğretmenin adı:
9. Bilimin doğası üzerine ders aldınız mı? Evet/Hayır
 - a. Evet ise hangi dersler olduğunu yazınız.
10. Fen öğrenmekten keyif alıyor musunuz?
11. Takip ettiğiniz bilimsel yayınlar (web sitesi, popüler bilim dergisi, podcast, belgesel vb) var mı: Evet/ Hayır
 - a. Varsa, isimleri nelerdir?
12. Ailenizde yada yakın çevrenizde bilim insanı veya bilim üzerine sohbet ettiğiniz insanlar var mı? Evet/Hayır
 - a. Varsa, lütfen kısaca hangi bilim alanında ya da hangi konularda sohbet ettiğinizi kısaca açıklayınız.
13. Bunlar dışında okul içinde veya dışında katıldığınız bilimsel etkinlikler var mı?
Evet/ Hayır
 - a. Varsa, lütfen kısaca açıklayınız?

14. En keyif aldığınız fen öğrenme deneyiminizi paylaşır mısınız? (okuldaki fen dersi veya farklı ortamlarda etkinlikler olabilir). Bunları sizin için olumlu kılan nedir?



APPENDIX D

THE VIEWS ABOUT SCIENTIFIC INQUIRY QUESTIONNAIRE

Bilimsel Sorgulama Hakkındaki Görüşler Anketi

Sevgili öğretmen adayları,

Aşağıda yer alan sorular bilimsel sorgulamaya ilişkin görüşlerinizi belirlemek amacıyla hazırlanmıştır. Anketi samimiyetle cevaplandırmanızı bekler, araştırmaya katkınızdan dolayı teşekkür ederiz.

Tarih:

Kod İsim:

1- Kuşlarla ilgilenen bir insan farklı türlerde besin yiyen yüzlerce farklı türdeki kuşu incelemiştir. Benzer türde besin yiyen kuşların gagalarının şeklinin de benzer olduğunu fark etmiştir. Örneğin, sert kabuklu fındık yiyen kuşlar kısa ve sert gagaya, böcek yiyen kuşlar ise uzun ve zayıf gagaya sahiptir. Bu kişi bir kuşun gaga şekliyle yediği besin türü arasında ilişki olup olmadığını merak etmiş ve bu soruya cevap bulmak için veri toplamaya başlamıştır. Kuşların gaga şekliyle yediği besin türü arasında bir ilişki olduğu sonucuna ulaşmıştır.

a. Bu kişinin araştırmasının bilimsel olduğunu düşünüyor musunuz? Lütfen neden olduğunu / olmadığını açıklayınız.

b. Bu kişinin araştırmasının bir deney olduğunu düşünüyor musunuz? Lütfen neden olduğunu / olmadığını açıklayınız.

c. Bilimsel araştırmalarda birden fazla yöntem izlenebileceğini düşünüyor musunuz?

· Hayırsa, lütfen neden bilimsel araştırmalarda tek bir yöntem izlenebileceğini açıklayınız.

· Evetse, lütfen farklı yöntemler içeren iki araştırma tanımlayınız ve bu yöntemlerin nasıl farklılaştığını ve nasıl hala bilimsel olarak kabul edilebileceklerini açıklayınız.

2- İki öğrenciye bilimsel araştırmaların her zaman bir soruyla mı başlaması gerektiği sorulmuştur. Öğrencilerden biri “evet” derken diğeri “hayır” demiştir. Siz hangisine katılıyorsunuz ve neden? Bir örnek vererek açıklayınız.

3- a) Eğer bilim insanları aynı soruyu araştırıyor ve veri toplamak için aynı yöntemleri izliyorsa, hepsi aynı sonuçlara mı ulaşır? Neden olduğunu/olmadığını açıklayınız.

b) Eğer bilim insanları aynı soruyu araştırıyor ve veri toplamak için farklı yöntemleri izliyorsa, hepsi aynı sonuçlara mı ulaşır? Neden olduğunu/olmadığını açıklayınız.

4- Lütfen “veri” ve “kanıt”ın birbirinden farklı olup olmadığını açıklayınız. Bir örnek veriniz.

5- Bir gün bilim insanlarından oluşan iki takım laboratuvarlarına doğru yürürken lastiği patlamış bir arabanın kenara çektiğini görürler. İki takımda “Bazı markaların lastikleri patlamaya daha mı yatkındır?” diye sorar.

· A takımı laboratuvara geri dönmüş ve birçok değişik lastiğin performansını üç farklı yol yüzeyinde test etmiştir.

· B takımı laboratuvara geri dönmüş ve bir marka lastiği üç farklı yol yüzeyinde test etmiştir.

Bir takımın diğerrinin izlediği yoldan neden daha iyi olduğunu açıklayınız.

6- Aşağıdaki tabloda gösterilen veriler, bir hafta içinde bitki büyümesi ve her gün alınan ışığın dakika sayısı arasındaki ilişkiyi göstermektedir.

Her gün alınan ışığın dakikası	Bir haftalık bitki büyümesi (cm)
0	25
5	20
10	15
15	5
20	10
25	0

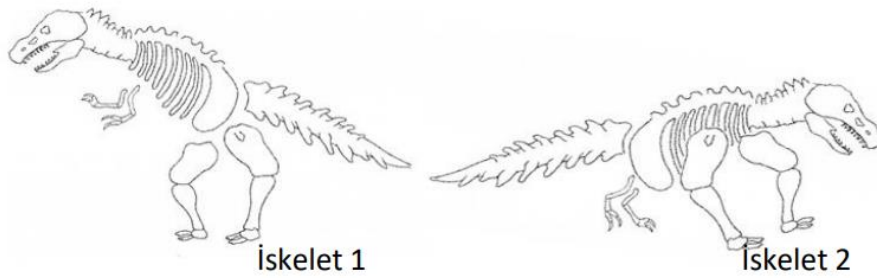
Bu verilere göre, aşağıdaki sonuçlardan birini seçiniz ve hangisine katıldığınızı açıklayınız.

- ☐ Bitkiler daha fazla güneş ışığı ile daha uzun büyürler.
- ☐ Bitkiler daha az güneş ışığı ile daha uzun büyürler.
- ☐ Bitkilerin büyümesinin güneş ışığı ile bir ilgisi yoktur.

a. Neden bu sonucu tercih ettiniz?

b. Veriler beklediğiniz gibi mi? Neden evet/hayır?

7- Bir grup bilim insanı bir dinazorun fosilleşmiş kemiklerini bulmuştur. Bu bilim insanları kemikleri iki olası düzenlemeyle birleştirmiştir.



- a. Bu düzenlemelerden neden çoğu bilim insanının kemiklerin yerleştirilmesinde 1 nolu iskeletin en iyi olduğuna karar vereceği yönündeki görüşünüzü en az iki sebeple açıklayınız.

- b. Yukarıdaki soruya verdiğiniz cevap düşünıldüğünde, bilim insanları kendi sonuçlarını açıklarken ne tür bilgiler kullanırlar?
- c. Bilim insanları herhangi bir araştırma sırasında, kendi sonuçlarını açıklarken ne tür bilgiler kullanırlar?



APPENDIX E

FIRST INTERVIEW QUESTIONS

Int1 Questions

1. Uyguladığınız ders hangi seviye ve kazanıma göre hazırlandı?
2. Bu uygulamada öğretmen olarak sizin amacınız neydi?
 - a. Kazanıma ek olarak başka hedefleriniz var mıydı (bilgi, beceri, NOS ve epistemology)
 - b. Bu dersin odağındaki bilimsel açıklama neydi?
3. Ders planının en önemli kısmını gösterebilir misiniz? Neden bu kısmın çok önemli olduğunu düşünüyorsunuz?
4. Dersi planladığınız gibi gerçekleştirebildin mi? Öğrenciler bu derste neler öğrenmişlerdir?
 - a. Bir daha bu dersi uygulayacak olsanız neyi değiştirirdiniz?
5. Dersinizde hangi bilimsel pratikleri kullandınız? Örnekle açıklayınız.
6. Dersinizde veri ve/veya kanıt kullandınız mı?
 - a. Eğer kullandıysanız,
 - i. Veri ve kanıtlardan ne şekilde faydalandınız? (Neden veri ve kanıt kullanma ihtiyacı duydunuz?) Örnekle veriniz.
 - ii. Bu veri ve kanıtlar amacınıza ulaşmak için yeterli miydi? Yeterli değilse, başka ne şekilde güçlendirilebilir?
 - iii. Bu veri ve kanıtların güvenilir olduğunu düşünüyor musunuz?
 - b. Eğer kullanmadıysanız:
 - i. Kullanılabilir miydi?
 - ii. Bilimsel açıklamayı ne şekilde desteklediniz?
7. Veri ve kanıtın birbirinden farklı olup olmadığını açıklayınız. Bir örnek veriniz.
8. Bilimde ve bilimsel açıklamalarda veri ve kanıtların rolü nedir?
9. Fen eğitiminde veri ve kanıtların rolü nedir?

APPENDIX F

SECOND INTERVIEW QUESTIONS

Int2 Questions

1. Uyguladığınız ders hangi seviye ve kazanıma göre hazırlandı?
2. Bu uygulamada öğretmen olarak sizin amacınız neydi?
 - a. Kazanıma ek olarak başka hedefleriniz var mıydı (bilgi, beceri, NOS ve epistemology)
 - b. Bu dersin odağındaki bilimsel açıklama neydi?
3. Ders planının en önemli kısmını gösterebilir misiniz? Neden bu kısmın çok önemli olduğunu düşünüyorsunuz?
4. Dersi planladığınız gibi gerçekleştirebildin mi? Öğrenciler bu derste neler öğrenmişlerdir?
 - a. Bir daha bu dersi uygulayacak olsanız neyi değiştirirdiniz?
5. Dersinizde hangi bilimsel pratikleri kullandınız? Örnekle açıklayınız.
6. Dersinizde veri ve/veya kanıt kullandınız mı?
 - a. Eğer kullandıysanız,
 - i. Veri ve kanıtlardan ne şekilde faydalandınız? (Neden veri ve kanıt kullanma ihtiyacı duydunuz?) Örnekle veriniz.
 - ii. Bu veri ve kanıtlar amacınıza ulaşmak için yeterli miydi? Yeterli değilse, başka ne şekilde güçlendirilebilir?
 - iii. Bu veri ve kanıtların güvenilir olduğunu düşünüyor musunuz?
 - b. Eğer kullanmadıysanız:
 - i. Kullanılabilir miydi?
 - ii. Bilimsel açıklamayı ne şekilde desteklediniz?
7. Benzen Halkası Modeli elementleri ve arasındaki ilişkileri göz önünde bulundurarak, ikinci ders planının ve uygulamanda hangi elementleri ve ilişkilendirmeleri kullandınız? Örneklerle açıklayabilir misiniz? (Burada Benzene Halkası Modeli gösterilir).

8. Benzen Halkası Modeli elementleri ve arasındaki ilişkileri göz önünde bulundurarak, birinci ders planında ve uygulamanda hangi elementleri ve ilişkilendirmeleri kullandın? Örnekleriyle açıklayabilir misin? (Burada Benzene Halkası Modeli gösterilir).

a. 1.ders planındaki veri-kanıt kullanımı ve kanıtlara dayalı açıklamaları değerlendirebilir misin?

9. Veri ve kanıtın birbirinden farklı olup olmadığını açıklayınız. Bir örnek veriniz.

10. Bilimde ve bilimsel açıklamalarda veri ve kanıtların rolü nedir?

11. Fen eğitiminde veri ve kanıtların rolü nedir?

Ekleme istediğiniz bir şey var mı?

Teşekkür ederim.

APPENDIX G

PROGRAM EVALUATION INTERVIEW QUESTIONS

Int3 Questions:

- 1) Bu derste veri ve kanıt kullanımı ile ilgili neler öğrendin?
- 2) Dönem boyunca gerçekleştirdiğimiz etkinlikleri birlikte hatırlayalım (Her hafta ile ilgili etkinlikler sırayla gösterilir ve dersin odağı belirtilir). Soruları cevaplarırken bu etkinlikleri düşünerek değerlendirme yapmanı isteyeceğim.
 - a) Bu etkinliklerde bilimde veri ve kanıtların rolü ve önemi ile ilgili neler öğrendin?
 - b) Bu etkinlikler fen eğitiminde veri ve kanıt kullanımının rolü ve önemi ile ilgili neler öğrendin?
 - c) Bu etkinlikleri geliştirmek için önerilerin nelerdir? (etkinlik, uygulama süreci vb).
 - d) Fen eğitiminde veri ve kanıtların rolü ve önemini fark ettiğin nokta eğitimin/etkinliklerin hangi aşamasındaydı?
 - e) Bilimde veri ve kanıtların rolü ve önemini tartışmak ders planı hazırlama sürecini değiştirdi mi? Nasıl?
 - f) Bilimde veri ve kanıtların rolü ve önemini tartışmak ders planını sınıf ortamında uygulama sürecini değiştirdi mi? Nasıl?
- 3) Ders planı hazırlama sürecini düşündüğünüzde, sizce bu çalışmanın amacı neydi?
 - a) Bu süreçte yapılan çalışma, tartışma ve geri bildirimler sırasında veri ve kanıtların fen eğitiminde kullanımı ile ilgili neler öğrendin?
 - b) Bu süreç ders planı hazırlama sürecine nasıl etki etti?
 - c) Bu süreç ders planını uygulama sürecine nasıl etkili etti?
 - a) Bu etkinlikleri geliştirmek için önerileriniz nelerdir? (etkinlik, uygulama süreci vb).

APPENDIX H

LESSON PLAN TEMPLATE

1. Grade Level and Topic:
 2. Expected pre-knowledge about the topic: Briefly describe what students already learned about this topic in earlier grades and previous lessons.
 3. Objectives: Write specific objectives which are based on specific learning activities you select and aligned with the national curriculum. If appropriate, one of your objectives should concern some aspect of the nature of science.
 4. Common/Anticipated Misconceptions: Review the literature and find common misconceptions related to the concepts you plan to teach and consider addressing these misconceptions through learning activities.
 5. Science Practices: List the science practices students develop through participation.
 6. Materials & Equipment Needed: List what you will need to teach this lesson.
 7. Body of the Lesson: Describe the sequence of activities as a numbered list. (List should reflect 5E model of instruction)
 1. Engagement
 2. Exploration
 3. Explanation
 4. Elaboration
 5. Evaluation
 8. Overplan: Briefly describe what you will do if you finish the lesson early. It should be more imaginative than ask questions and give examples.
 9. References: List references in APA format
 10. Worksheets: Attach worksheets as separate pages
- (Note: Plan should not exceed 2 pages excluding worksheets)

APPENDIX I

A CODED LESSON PLAN USING CODEBOOK-2

Code
4a

How can we utilize simple machines
to lift a heavy box?



Code
4a

- Let's conduct an experiment using a simulation to find an answer to the question: What factors contribute to gaining a force advantage on an inclined plane?

Code
2a

- To answer this question, let's identify the variables:
 - Independent Variable:
 - Dependent Variable:
 - Control Variable:

Code
4a

- Mark your prediction.
As the length of the inclined plane increases, the applied force INCREASES / DECREASES / REMAINS THE SAME.

Codes
3b
2b

- Complete the table using the data obtained from the simulation.

Codes
1a
4a



	Length of the inclined plane	Height of the inclined plane	Applied force
Case 1			
Case 2			
Case 3			
Case 4			

Code
3a

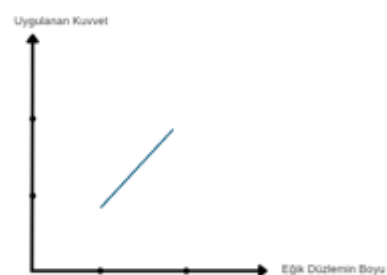
- What is the difference between the first case and the other three cases? Compare the applied force in the first case with the applied forces in the second, third, and fourth cases. What characteristic of the inclined plane did you discover based on this comparison? Explain.

6. Organize the data table in a way that helps answer the research question.

Codes 2b 3b		Length of the inclined plane	Height of the inclined plane	Applied force
	Case 1			
	Case 2			
	Case 3			
	Case 4			

Code
3b

7. Using the data from the table, represent the relationship between the length of the inclined plane and the applied force in a line graph.



Codes
1a
2b
4a

Codes
3a
4a
3b

8. Explain the relationship between the length of the inclined plane and the applied force by providing evidence.

APPENDIX J

SCIENCE LESSONS OBSERVATION TASK

For classroom observation task report, you are expected to make observations in the classroom environment and to analyze a unit of the MEB textbook to examine the use of data and evidence in providing evidence-based explanations.

Warnings:

- You must observe at least four lessons and among those four lessons choose at least two scientific explanations. Analyze its relation to data/evidence using the guiding questions below.
- Your textbook analysis must involve at least two data/evidence based scientific explanations.
- You can collect classroom data together with your internship partner.
- You can select the same unit and analyze the textbook together with your internship partner.
- You will write and submit your report individually.

Format of the Task Report

1. Title of Topic
2. Introduction - Introduce the topic (describe what this task is about...)
3. Method

For observations: Participants (explain the demographics of the lessons you observed including the number of students, grade level, topic, objective, and the brief information about the teacher, duration of observation)

For textbook analysis: Describe the resource you used (grade level, name of the unit, objectives of the unit, publisher information)

4. Results –

a. Analyze the two observed scientific explanations using the guiding questions provided in the table below.

Analysis of observed lessons (for each explanation provide separate tables)

Observed Lesson Date/Time:		
Name of teacher		
Grade Level:		
Topic/Objective		
Number of students:		
Guiding questions	Select the appropriate options	Describe the context
Was there any data/evidence?	Yes/No	(please describe the lesson briefly)
How was the data/evidence obtained?	Through Experiment / Observation / Classification/ Evidence Texts	
	First-hand / Second-hand / Both / None	
What type of data/evidence were used?	(Statistical / Verbal / Visual, Historical / Graphical / Resources / Other / None	
Which practices were used in integration of data/evidence?	Measure / Collect / Organize / Represent / Analyze / None	
Was the data/evidence connected to scientific explanation? How?	Yes/No	
	Supporting / Contradicting / None	
Additional Notes:		

b. In this section, analyze observed scientific explanations in the MEB textbook in terms of use of data and evidence. Use the table below to report your analysis.

Provide screenshots of the related sections of the textbook as evidence.

Screenshots:

Analysis of text book (for each explanation provide separate tables)

Title of the Unit		
Grade Level:		
Topic/Objective		
Guiding questions	Select the appropriate options	Describe the context
Describe the data/evidence		
Describe related scientific explanation		
Was the data/evidence connected to scientific explanation? How?	Yes/No Supporting / Contradicting / None	
How was the data/evidence presented?	Through Experiment / Observation / Classification/ Evidence Texts	
	First-hand / Second-hand / Both / None	
What type of data/evidence were presented?	(Statistical / Verbal / Visual, Historical / Graphical / Resources / Other / None	
Which practices were encouraged in integration of data/evidence?	Measure / Collect / Organize / Represent / Analyze / None	
Additional Notes:		

5. Discussion and Conclusion – Discuss and conclude your work with suggestions for better practice.

a. Evaluate the use of data/evidence based scientific explanations during the lessons and in textbooks. Were they sufficient? Why?

b. Compare and evaluate the use of data and evidence used in providing scientific explanations both in the lessons and textbook was appropriate and adequate to generate evidence-based explanations.

c. How could you improve the quality of the lesson to generate these scientific explanations? Suggest a specific activity to incorporate data and evidence in providing evidence-based explanations to achieve the goals of the lessons.

APPENDIX K

SAMPLE LESSON PLAN ACTIVITY

LESSON PLAN

1. Grade Level and Topic: 7th Grade; Topic- Kuvvet, İş ve Enerji ilişkisi

2. Expected pre-knowledge about the topic:

F.5.5.4.2. Tam gölgeyi etkileyen değişkenlerin neler olduğunu deneyerek keşfeder.

F.5.7.2.1. Bir elektrik devresindeki ampul parlaklığını etkileyen değişkenlerin neler olduğunu tahmin ederek tahminlerini test eder.

F.6.7.2.1. Bir elektrik devresindeki ampulün parlaklığının bağlı olduğu değişkenleri tahmin eder ve tahminlerini deneyerek test eder.

F.7.3.2.1. Fiziksel anlamda yapılan işin, uygulanan kuvvet ve alınan yolla ilişkili olduğunu açıklar.

3. Objectives:

MEB kazanımı:

F.7.3.2.2. Enerjiyi iş kavramı ile ilişkilendirerek, kinetik ve potansiyel enerji olarak sınıflandırır.

Dersin kazanımı:

- Kinetik enerjinin cismin kütlesi ve süratiyle olan ilişkisini gösteren verileri analiz eder.
- Kinetik enerjinin cismin kütlesi ve süratiyle olan ilişkisini açıklar.

Next Generation Science Standards:

HS-PS3-1. Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object.

4. Common/Anticipated Misconceptions

-Some people think doubling speed means doubling the energy (Liu and Fang, 2017).

-Kinetic energy depends on mass only (Liu and Fang, 2017).

-Some people think doubling speed increases the energy as the same of doubling the mass (Liu and Fang, 2017).

5. Science Practices:

- Asking Questions and Defining Problems
- Developing and Using Models
- Analyzing and Interpreting Data.
- Using Mathematics and Computational Thinking.
- Constructing Explanations
- Engaging in Argument from Evidence
- Obtaining, evaluating, and communicating information.

6. Materials & Equipment Needed:

- Worksheet
- Presentation
- Video
- Computer

7. Body of the Lesson

1. Engage: 6 minutes

Teacher presents a short video (Video-1) on asteroids and underlines that some of the asteroids could enter the atmosphere of the Earth. Then, the teacher asks: 'Could an asteroid colliding with Earth cause a mass extinction?' and facilitates students to explain the reasons of their answers. It is explained that foundations in various countries such as NASA make observations in space on asteroids. According to NASA data, there has been approximately 600 asteroids identified that entered to the atmosphere. Then, the teacher asks the variables regarding the asteroids that NASA could be considering as a danger that may harm the Earth. Student answers are fostered and written on a corner of the board. Examples are: mass, density, volume, speed, rotation, radius (some of those are related to each other and can be expressed during discussion).

Then, teacher leads the students to select two of these variables (mass and speed) with the aim of working on their influence during a collision. To do that, a video that shows an asteroid hitting the Earth (Video-2 first 18 seconds) is presented. The reason of the fireball and the movements of the Earth in the video is highlighted. This is connected to the previous lessons that students learned the Energy concept and types of energy, specifically the kinetic energy.

To connect to the initial question and variables, the teacher reminds that 'The asteroid will be traveling very fast when it hits the surface of the planet.' And leads students to the following scientific questions regarding the variables.

- How does the energy change with the mass of the asteroid?
- How does the energy change with the speed of the asteroid?
- Should we focus on the mass of the asteroid or worry about its speed?

2. Explore: 18 minutes

Teacher spread the worksheet to students and explains that they will receive some experimental data that NASA research scientists determined for the KINETIC ENERGY of the impact of an asteroid. Before working on tasks, the teacher clarifies the tasks they will follow. They will be working on data tasks to answer the scientific questions asked. A reminding on definitions of dependent/independent/control variables can be made to students if they need. Students work in pairs to complete the worksheet. Teacher walks around the groups to check the progress and facilitate them. Visit the Worksheet-1 for the detailed flow of this section. Sample drawing of graphs can be found in Appendix-1.

3. Explain: 10 minutes

In the worksheet, students were asked to answer open ended questions after each task which provide opportunity to construct scientific explanations to the relationships of kinetic energy to the mass of an object and to the speed of an object. In classroom discussion, students will be asked to state and explain their answers to those questions. Then, teacher summarizes students' answers and concludes that "you have found these results and made scientific explanations. Scientists also conduct experiments, collect data, and analyze them as you do. They say similar things to your explanations". After this, the teacher summarizes scientific information and presents the kinetic energy and its relationship with mass and speed.

Additional Information: In physics, KINETIC ENERGY is the energy an object has BECAUSE of its motion. Kinetic energy is also a measure of how much change an object can cause.

- a *larger* moving object will do more damage (cause more change) than a *smaller* moving object.
- a *faster* moving object will do more damage (cause more change) than a *slower* moving object.

4. Elaborate: 4 minutes

For elaboration on the relationship of kinetic energy with speed and mass of an object, a cartoon is presented to students as a case that shows a truck and a car with the same speed hits a wall. Truck and car are expected to have different masses. They are asked which collision will do more damage to the wall. Whole class discussion is facilitated.

See Appendix-2 below for the cartoon.

5. Evaluate: 3 minutes

In this part, a true/false game in a suitable platform that can be used in classroom (i.e., Kahoot or worksheet). See Worksheet-2.

8. Overplan

A NASA video on potential and kinetic energy can be watched and discussed.

9. References

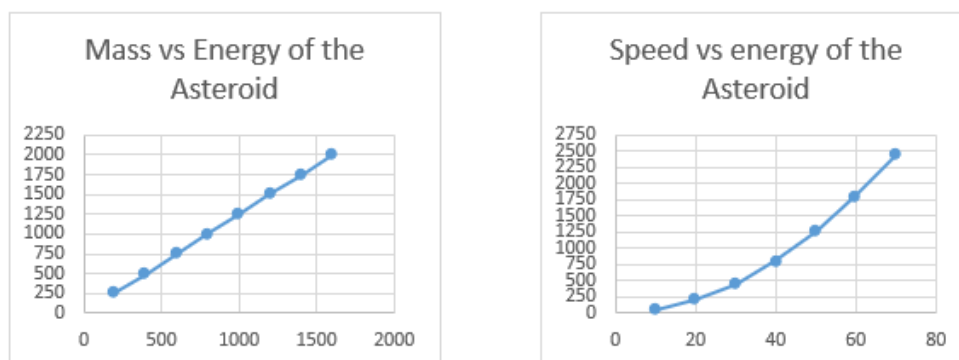
Asteroid video -1 : <https://www.youtube.com/watch?v=zWgQvMgX2oU>

Asteroid video -2 : <https://www.nasa.gov/planetarydefense/faq>

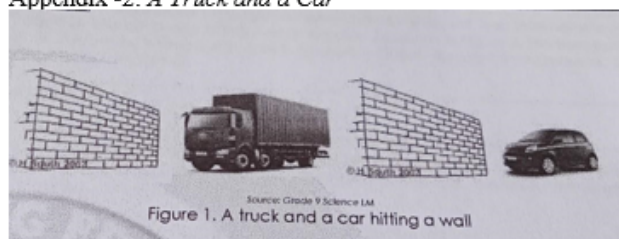
Nasa Video: <https://www.nasa.gov/stemonstrations-energy.html>

Liu, G., & Fang, N. (2017, March). Student misconceptions of work and energy in engineering dynamics. In *Proceedings of the 2017 ASEE Gulf-Southwest Section Annual Conference*. University of Texas at Dallas.

Appendix -1: Sample drawings for the graphs:



Appendix -2: A Truck and a Car



Worksheet-1

Could an asteroid colliding with Earth cause a mass extinction?

The asteroid will be traveling very fast when it hits the surface of the planet. We should consider the following scientific questions:

- *How does the energy change with the mass of the asteroid?*
- *How does the energy change with the speed of the asteroid?*
- *Should we focus on the mass of the asteroid or worry about its speed?*



Figure 1. An asteroid colliding with Earth

You will receive some experimental data that NASA research scientists determined for the KINETIC ENERGY of the impact of an asteroid. Use the data to answer the questions.

TASK-1:

- *How does the energy change with the mass of the asteroid?*

Select one option for your prediction:

When mass increases, Kinetic energy increases/decreases/stays the same.

- A) Examine the above question and Table-1 below. Then, identify and write the variables to answer the question:

Dependent Variable:

Independent Variable:

Control Variables:

- B) Examine and organize the data in Table-1. Write the organized data into Table-2. Consider the sequence of the data that makes it easier to read and identify patterns and relationships.

Table 1. Mass vs Energy data of the asteroid.

MASS (kg) experimental lander velocity = 50 m/s	Energy (kilojoules)
400	500
1000	1250
600	750
1600	2000
200	250
800	1000
1400	1750
1200	1500

Table 2. Organized Data for Mass vs Energy of the asteroid.

MASS (kg) experimental lander velocity = 50 m/s	Energy (kilojoules)

- C) Draw a graph to observe the relationship between mass and energy of an asteroid.

								Guidance to draw a graph:
								1. Draw and label the axes for your data on the given graph paper
								2. Label your axes with a proper SCALE so that your data will FILL the graph
								3. Plot the points on your own paper
								4. Connect the dots to see the relationship

Answer the following questions in complete sentences.

- 1-What happens to the kinetic energy when the mass of the asteroid increased?
- 2-Check you prediction and state whether it has changed or not.
- 3- What is the shape of the MASS vs ENERGY graph? Is it a LINEAR RELATIONSHIP?
- 4- What happens when you DOUBLE the mass?

TASK 2:

- *How does the energy change with the speed of the asteroid?*

Select one option for your prediction: When speed increases, Kinetic energy increases/decreases/stays the same.

- A) Examine the above question and Table-3 below. Then, identify the variables to answer the question:

Dependent Variable:

Independent Variable:

Control Variables:

- B) Examine and organize the data in Table-3. Write the organized data in Table-4. Consider the sequence of the data that makes it easier to read and identify patterns and relationships.

Table 3. Velocity vs Energy Data of the Asteroid

Speed (m/s) experimental lander mass = 1000 kg	Energy (kJ)
20	200
60	1800
40	800
10	50
80	3200
30	450
70	2450
50	1250

Table 4. Organized Data for Speed vs Energy Data of the Asteroid

Speed (m/s) experimental lander mass = 1000 kg	Energy (kJ)

- C) Draw a graph to observe the relationship between mass and energy of an asteroid.

								Guidance to draw a graph: 1. Draw and label the axes for your data on the given graph paper 2. Label your axes with a proper SCALE so that your data will FILL the graph 3. Plot the points on your own paper 4. Connect the dots to see the relationship

Answer the following questions in complete sentences.

- 1-What happens to kinetic energy when you increase speed?
- 2-Check your prediction and state whether it has changed or not.
- 3-What is the shape of the VELOCITY vs ENERGY graph? Is it a *LINEAR RELATIONSHIP*?
- 4-What happens when you DOUBLE the velocity?

TASK 3:

- Should we focus on the mass of the asteroid or worry about its speed?

Examine both of your graphs you have drawn for Mass vs Energy and Speed vs Energy to answer the following questions.

- 1-How can a small object (small mass) have the same energy as a large object (large mass)?
- 2-Which makes a bigger difference: a 100 kg increase in the mass or a 100 meter/sec rise in velocity?
 - Write down your decision and explanation for the question: *Should we focus on the mass of the asteroid or worry about its speed?*

Worksheet 2

This Part can be used as a true/false game in a suitable platform that can be used in classroom (i.e., Kahoot)

DATA MATCH: CIRCLE the statements (more than one) that agree with the graphs you made.

1. Kinetic energy increases when mass increases.
2. Kinetic energy decreases when speed increases.
3. A small object (small mass) can have the same kinetic energy as a large object (large mass) IF its velocity is large enough
4. The shape of the MASS vs ENERGY graph has a *NON-LINEAR RELATIONSHIP*.
5. The VELOCITY vs ENERGY graph shows a *NON-LINEAR RELATIONSHIP*.
6. An increase in velocity of 100 m/s leads to a LARGER increase in kinetic energy than an increase of 100 kg.

APPENDIX L

SUMMARY OF THE DESIGNED COURSE FOR THE 2ND CYCLE

Theme-1: Exploring Prior Knowledge

Topic	Purpose	Activities
Exploring Prior Knowledge	Exploring prior knowledge about data/evidence and evidence-based explanations to make necessary connections throughout the course.	1. VASI 2. LP1: Designed and practiced by PSTs. 3. Int1: Interviews to reflect on a PST's LP1 and TP1

Theme-2: Role and Use of Evidence

Topics	Purpose	Activities
Data/Evidence and Scientific Practices in Science	Developing a conceptual understanding of: • the growth of scientific knowledge • scientific practices from a holistic perspective • the role of evidence in science and scientific practices • components of scientific practices and their relationships as represented in the BRH	1. Concept Cartoons Activity: Discussion on the growth of scientific knowledge 2. Concept Map Activity: design and present a concept map using fundamental scientific terms (e.g., theory and data), followed by a discussion. 3. Classroom Discussion: Introduction to scientific practices and the BRH. -Define and provide examples of each BRH component -evaluate the interconnections of the components -analyze the relationships between scientific practices in the BRH 4. Age of the Earth Activity: A video featuring a scientist discussing the use of evidence in science, followed by classroom discussion

Theme-2: Role and Use of Evidence (...continued)

Topics	Purpose	Activities
Data/Evidence and Scientific Practices in Science Education	Developing an understanding of: - the role of data/evidence and scientific practices in the science education curriculum - the construction of evidence-based scientific explanations and their connection to BRH components. - Relationships between scientific practices and the components of BRH	- Weather Forecast Scenario Activity: PSTs identify components of scientific practices represented in the BRH and evaluate their interconnections in the given scenario related to a subject matter in curriculum. - Curriculum Analysis Activity: Analysis of curriculum materials with respect to scientific practices through the lens of the BRH (Group activity followed by a class discussion) - Reflection Activity: Revisiting first lesson plans to reflect on the use of scientific practices in LP1

Theme-3: Evidence Integration

Topic	Purpose	Activities
Integration of Data/Evidence through Data Transformations	Developing an understanding of designing instructional materials in relation to data/evidence through - The integration of scientific practices in science lessons - The use of EE through data transformations such as organization, representation, and pattern identification to construct evidence-based explanations in science lessons. - use of first-hand and second-hand data in classroom environment - the evaluation of lesson plans based on scientific practices represented in BRH	Sample Lesson Plan Activity-1: Lesson plans, designed by the researcher, used as instructional materials. - Analyze lesson plans in groups (physics, chemistry, biology) in the lens of scientific practices in BRH and data transformations in EE - Classroom discussion: -evaluate the interconnections of scientific practices -evaluate data transformation -discuss the use of various forms of data and evidence in science and science lessons -assess the reliability of evidence

Theme-3: Evidence Integration (...continued)

Topic	Purpose	Activities
Integration of Data/Evidence through Model-Evidence Link Diagram	Developing an understanding of: • construction of evidence-based scientific explanations • evaluation of evidence in supporting or refuting scientific explanations. • use of various types of data/evidence in science and science lessons • Contribution of evidence-based instructions on students' learning • Determination of the appropriateness of a materials by evaluating classroom conditions and activity structures.	1. MEL Activity: • PSTs work in groups to complete MEL on nuclear energy (Small group activity moderated by the instructor) • Classroom discussion on various forms of data and evidence, reliability of evidence and resources, and use of evidence-texts in science lessons. 2. Expert Speaker Activity: A science educator-experienced in scientific practices research facilitates discussion on the content and use of the MEL as an instructional material for evidence-based science lessons. • Presentation of research studies and findings related to the MEL conducted within the Turkish context. • Opinions of experienced teachers on appropriateness, advantages, and challenges of MEL implementation • the implementation of MEL in real classroom setting and its impact on students' learning
Integration of Evidence through Scientific Activities	Developing an understanding of data/evidence integration in different types of scientific activities that lead to	Video Cases Activity: Discussion and analysis of video-based teaching examples and evidence integration in the design of different scientific activities (e.g., observation)

Theme-4: Evaluation of Use of Evidence

Topic	Purpose	Activities
Evaluation of Sample Lesson Plans in terms of Evidence	Developing an understanding on • integration of scientific practices in design of lessons • use of evidence to construct scientific explanations in lessons. • analysis and evaluation of lesson plans based on BRH and guiding questions	1. Sample Lesson Plan Activity-2: Previous PSTs' lesson plans designed and implemented in internship schools were selected as instructional material. • Group activity to analyze lesson plans in the lens of scientific practices in BRH and data transformations in Evidence-Explanation Continuum • Classroom discussion: -evaluation of the interconnections of scientific practices -evaluation of data transformation -use of various forms of data and evidence in science and science lessons -reliability of evidence
Evaluation of Participants' Lesson Plans in terms of Evidence	Developing an understanding of data/evidence integration to construct scientific explanations in lesson plans	1. Sample Lesson Plan Activity-3: Feedback and reflection session on volunteer PST's presentation of second lesson plans (classroom discussion)
Evaluation of Mentor Teachers' Instruction and Textbooks in terms of data/evidence	Developing an understanding of the use of evidence in science education at micro level through analysis of real classroom environments and national textbooks	1. Science Lesson Observation Task: PSTs complete a task to report and present their findings of: • their observation of mentor teachers' practice at internship schools, data collection & analysis on integration of evidence in providing explanations • their analysis of the MEB textbook to examine the use of data and evidence in providing evidence-based explanations. • their suggestions for integrating data/evidence to improve science.

Theme-5: Evidence-based Teaching Practice

Topic	Purpose	Activities
Evidence-based Teaching Practice	-Designing a lesson plan with evidence integration -Teaching practice at K12 schools	1. LP2 Design: • Feedback and discussion meetings during LP2 design (Sessions conducted with the instructor in pairs) 2. Teaching Practice 2: • Observation of teaching practice of PST's (individual) • participation in interviews to reflect on lesson plans and teaching practice of PST's own work
Program Evaluation	Reflecting on the designed program PSTs attended	Individual interview sessions for PSTs to evaluate the designed course in relation to their learning.

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