CHALLENGES OF PRE-SERVICE PHYSICS TEACHERS IN ARGUMENT-DRIVEN INQUIRY ACTIVITIES

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ABSTRACT

CHALLENGES OF PRE-SERVICE PHYSICS TEACHERS IN ARGUMENT-DRIVEN INQUIRY ACTIVITIES

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This study aimed to investigate challenges faced by pre-service physics teachers (PPTs) in an online course based on Argument-Driven Inquiry (ADI) as they acted as learners, planners, and instructors. An undergraduate elective course was redesigned for this purpose. The course, which is structured into learning, preparation, and teaching phases, involved four weekly hours during the fall semester of the 2020-2021 academic year. Analyzing challenges faced by the three lowest-achieving students in all phases enhanced understanding of PPTs' struggles with ADI. The study employed a qualitative approach, utilizing video recordings, course materials filled by/prepared by the participants, reflection papers, and interviews for data collection. A meticulous data analysis, following the constant comparative method, uncovered intricate challenges during the learning, preparation, and teaching phases of ADI. The findings reveal a number of issues related to different aspects of ADI, namely claims, empirical and theoretical data, empirical and theoretical warrant, and empirical rebuttal. Noteworthy is the finding that these challenges are content-dependent, suggesting that proficiency in one phase does not guarantee success in others. Implications emphasize the need for a holistic approach in teacher preparation, ongoing professional development, and curriculum design, addressing interconnected challenges and acknowledging the content and/or context dependency of skill development. Depagogical approaches tailored based on the challenges and specialized guidance are advocated, emphasizing the unique challenges encountered during the ADI activities The study contributes valuable insights to science education practices, urging educators and policymakers to consider the identified challenges for effective ADI implementation.

Keywords: Argumentation, Inquiry, Argument-Driven Inquiry, Challenges, Pre-service Physics Teachers

ÖZ

FİZİK ÖĞRETMEN ADAYLARININ ARGÜMAN ODAKLI SORGULAMA ETKİNLİKLERİNDE KARŞILAŞTIKLARI ZORLUKLAR

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Bu çalışmanın amacı, fizik öğretmen adaylarının (FÖA) çevrimiçi yürütülen Argüman Odaklı Sorgulama (AOS) odaklı bir derste öğrenci, geliştirici ve öğretmen olduklarında karşılaştıkları zorlukları araştırmaktır. Bu amaçla, seçmeli bir lisans dersinin içeriği yeniden tasarlanmıştır. Öğrenme, geliştirme ve öğretim aşamaları şeklinde yapılandırılan ders, 2020-2021 akademik yılının güz dönemi boyunca haftalık dört saatten oluşmuştur. Tüm aşamalarda en düşük başarıya sahip üç öğrencinin karşılaştığı zorlukların analiz edilmesi, FÖA'ların AOS ile mücadelelerinin anlaşılmasını sağlamıştır. Çalışmada nitel bir yaklaşım benimsenmiş ve veri toplamak için video kayıtları, ders materyalleri, yansıtma kağıtları ve görüşmeler kullanılmıştır. Sürekli karşılaştırmalı yöntemi izleyen bir veri analizi, AOS'ın öğrenme, geliştirme ve öğretim aşamalarındaki karmaşık zorlukları ortaya çıkarmıştır. Bulgular, iddialar, ampirik ve teorik veriler, ampirik ve teorik gerekçeler ve ampirik çürütme ile ilgili zorluklar da dahil olmak üzere çok yönlü sorunları ortaya koymaktadır. Bu zorlukların içeriğe bağlı olması dikkat çekicidir ve bir aşamadaki başarının diğerlerinde yeterliliği garanti etmediğini göstermektedir. Çıkarımlar, öğretmen hazırlığı, sürekli mesleki gelişim ve müfredat tasarımında, birbiriyle bağlantılı zorlukları ele alan ve beceri gelişiminin içeriğe ve/veya bağlama bağımlılığını kabul eden bütünsel bir yaklaşıma duyulan ihtiyacı vurgulamaktadır. AOS çerçevesindeki benzersiz zorluklar vurgulanarak, özel pedagojik yaklaşımlar ve özel rehberlik savunulmaktadır. Çalışma, fen eğitimi uygulamalarına değerli içgörüler katmakta, eğitimcileri ve politika yapıcıları etkili ADI uygulaması için belirlenen zorlukları dikkate almaya çağırmaktadır.

Anahtar Kelimeler: Argümantasyon, Sorgulama, Argüman Odaklı Sorgulama, Zorluklar, Fizik Öğretmen Adayları

To the 100th Anniversary of the Republic of Türkiye

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CHAPTER 1

INTRODUCTION

The terms “science” and “scientists” are commonplace in our everyday discourse. These terminologies hold a distinctive status, not solely within our daily interactions but also in the academic sphere. The attribution of the label “scientific” to certain assertions, rationales, or research endeavors is a deliberate act aimed at conveying a sense of value or a particular form of reliability, as articulated by Chalmers (1999). However, what attributes contribute to the esteemed regard accorded to science and its practitioners? It is imperative to scrutinize the underpinnings of the profound respect accorded to the realms of science and its practitioners. Primarily, it is important to elucidate the precise definitions of the concepts of “science” and “scientist”. As evidenced in the foregoing discussion, science represents a repository of reliable and empirically sound knowledge, while a scientist is an individual who, through the application of rigorous scientific methodologies, engenders this knowledge.

Science involves the systematic examination of natural phenomena within the universe. To comprehend the operations of the universe, scientists engage in formulating and substantiating claims through the acquisition of data from observations and experiments. The reciprocal process of critiquing each other’s assertions is undertaken to either disprove unsubstantiated claims or endorse those validated. As posited by Felton et al. (2009), the acquisition of scientific knowledge by scientists is facilitated through the comprehensive application of inquiry and argumentation as a whole. Inquiry, with historical roots, traced back to the Latin term “inquerere,” meaning to investigate, ask, and seek, has been an enduring component of scientific exploration (Online Etymology Dictionary, n. d.). The National Science Education Standards (National Research Council [NRC], 1996, 2000) define inquiry as the diverse methodologies scientists employ to pose questions to examine the natural world and construct rich explanations rooted in evidence. The definition of argumentation varies among scholars, with some characterizing it as the construction of scientific knowledge and others depicting it as the initiation of discourse to attain consensus. For example, while O'Keefe (1982) simplifies argumentation as a conclusive product derived from premises, Rieke and Sillars (1993) portray it as a *dialogical process* influencing individuals' perspectives through presenting, supporting, and modifying one's claims, and criticizing those of others. In essence, science, inquiry, and argumentation are inextricably intertwined.

Bruner (1960), a foundational figure in the field of science education, underscores the significance of conceptual learning in science education by portraying the learner as a scientist. In his articulated perspective, Bruner (1960) contends that a student engaged in learning physics essentially assumes the role of a physicist, highlighting the efficacy of aligning educational practices with the behaviors intrinsic to the scientific discipline. This statement is further echoed in the National Science Education Standards (NRC, 2000), which assert that students cultivate a profound comprehension of scientific laws, theories, models, and principles through active inquiry and emulation of scientific processes, aligning their approach with that of scientists. The well-known aphorism "Tell me and I forget, show me and I remember, involve me and I understand" encapsulates the value of learner participation in tasks as a potent mechanism for meaningful learning. Consequently, a departure from rote memorization becomes imperative in science education, given that the discipline transcends a mere repository of laws, theories, and facts, encompassing the dynamic processes integral to scientific inquiry (Driver et al., 1994). The pivotal role of learners' active participation in learning science, specifically through the processes of inquiry and argumentation, is emphasized. Following Kuhn's (2005) recommendations, the implementation of a learning environment of this nature can be achieved through the integration of inquiry and argumentation activities as part of classroom instruction.

In the realm of science education, both inquiry and argumentation methodologies enjoy widespread application, with documented advantages for students (e.g., Bell & Lin, 2000; Constantinou et al., 2018). In science education, instructional methods that integrate both inquiry and argumentation include Argument-Driven Inquiry (ADI) and Argument-Based Inquiry (ABI), as seamlessly demonstrated in the relevant literature (Hand et al., 2004; Walker et al., 2011). In the context of this study, ADI was favored due to its structured and systematic approach, where the inquiry process is intricately aligned with the systematic development and articulation of arguments.

1.1 Rationale of the Study

Introduced by Walker et al. (2011), ADI serves as an instructional method that places significant emphasis on argumentation within laboratory-based instructional settings (Walker & Sampson, 2013a). ADI instructional sessions commence with the formulation of a research question, guiding students to construct an argument comprising a claim, evidence, and reasoning as they work toward addressing the posed inquiry (Grooms et al., 2018; Sampson & Gleim, 2009). The delineated characteristics of ADI align with the requisites for an innovative science education approach.

Given the novelty of ADI as a pedagogical approach, there exists limited empirical research regarding its efficacy within educational settings. Nonetheless, as ADI inherently incorporates inquiry and argumentation processes, the educational outcomes associated with ADI encompass those associated with both inquiry-based and argumentation-based learning methods. Extensive educational research has demonstrated the advantageous effects of proficiently implementing inquiry and argumentation within science classrooms.

ADI is crafted with the primary objective of fostering students' autonomous development of methodologies for data collection, investigation, and utilization of data to address research inquiries, as well as proficiency in writing and reflective practices. Moreover, ADI provides students with opportunities to engage in argumentation and participate in peer review processes (Walker et al., 2011). The implementation of ADI in science learning yields notable advancements in students' argumentation skills (Sampson et al., 2011), writing proficiency (Sampson et al., 2013), evaluation of peer writings (Walker & Sampson, 2013b), conceptual understanding (Sampson et al., 2013), and attitudes toward science (Walker et al., 2012). Students immersed in inquiry activities exhibit enhanced conceptual understanding (Blanchard et al., 2010), science process skills (Mattheis & Nakayama, 1988), critical thinking abilities (Constantinou et al., 2018), communication skills (Shymansky et al., 1983), epistemological understandings (NRC, 2000), motivations (Cairns & Areepattamannil, 2019), and attitudes toward science (Gibson & Chase, 2002). By the same token, engagement in argumentation activities contributes to improvements in conceptual understanding (Berland & Reiser, 2009), argumentation skills (von Aufschnaiter et al., 2008), critical thinking abilities (Duschl & Osborne, 2002), communication skills (Osborne et al., 2004b), epistemological understandings (Bell & Linn, 2000), motivations (Bell & Linn, 2000), and attitudes toward science (Kutluca & Aydın, 2016). Considering these multifaceted benefits, a learning environment predominantly shaped by ADI activities is logically anticipated to facilitate robust knowledge construction among students.

Upon a thorough examination of the pertinent literature, it is evident that a prominent concern within the domain of science education revolves around the promotion of inquiry and/or argumentation activities. While a limited group of researchers in science education the field has made efforts to discern the reasons behind the infrequent utilization of such activities in learning environments, the prevailing studies predominantly attribute the non-implementation of these activities to external barriers. These external barriers encompass the implementation of inaccurate inquiry levels such as guided inquiry and open inquiry (Kirschner et al., 2006), time constraints (Newton et al., 1999), resource insufficiency (Edelson et al., 1999), and a deficit in pedagogical content knowledge (Yoon et al., 2012). In contrast, the internal challenges associated with teaching with these activities have not undergone a comprehensive analysis.

Nations are typically classified into developed, developing, and undeveloped categories. The transition from an industrial to an information society marks a country's classification as developed, encompassing widespread societal integration of this transformation. Achieving this transition is contingent upon advancements in science and technology. This underscores the significant emphasis that should be placed on science and science education in Türkiye, identified as a developing country (Aslan, 2019).

In Türkiye, curriculum revisions have been implemented since the academic year 2005-2006. Even though the use of student-centered learning approaches is recommended by the physics curriculum empirical investigations in Türkiye indicate a predominant reliance on traditional teaching methods among teachers in their classrooms (Aslan, 2019). There is a compelling need to investigate and comprehend the factors contributing to the limited adoption of student-centered methods, particularly that of ADI by physics teachers.

Prior to delineating the challenges faced by teachers in the implementation of ADI, it is methodologically sound to initially ascertain the challenges encountered by pre-service teachers (PPTs) and their origins. This strategic approach aims to provide a comprehensive understanding of how to effectively address these challenges, particularly considering the identified deficiency in teachers' pedagogical content knowledge as a notable external barrier to ADI implementation. Consequently, the research endeavors to focus on elucidating the challenges experienced by PPTs in both learning science with ADI and its subsequent implementation, specifically in scenarios where external barriers have been successfully mitigated.

1.2 Significance of the Study

This study holds significance as it addresses the prevalent issue of underutilizing inquiry and/or argumentation activities in science education. Specifically, it explores the internal challenges faced by PPTs during the implementation of ADI in online settings. Initially, by delving into the challenges experienced by PPTs in various roles as learners in ADI activities, as integrators of ADI into the Turkish physics curriculum, and as instructors implementing ADI activities; the research aims to provide insights that can inform the development of more effective educational practices, tailored teacher training programs and curriculums. The thorough examination of challenges encountered by the PPTs who participated in this study is anticipated to prompt the exploration of strategies aimed at overcoming these obstacles. This, in turn, is expected to facilitate the development of more effective learning environments in the field of science education. The focus on internal challenges adds depth to the scholarly discourse, addressing a specific aspect that has not been thoroughly explored and enriching the academic community’s understanding of the complexities involved in implementing innovative teaching methods.

1.3 Aims of the Study

The main aim of the study is to identify the challenges experienced by PPTs in various roles as learners in ADI activities, as integrators of ADI into the Turkish physics curriculum, and as instructors implementing ADI activities.

1.4 Research Questions of the Study

In consideration of the aforementioned purposes of this study, the following research questions are formulated:

RQ1. What are the challenges of PPTs in physics-oriented ADI activities?

RQ1.1 What are the challenges of PPTs acting as learners in ADI activities?

RQ1.2 What are the challenges of PPTs integrating ADI into the Turkish physics curriculum?

RQ1.3 What are the challenges of PPTs in acting as teachers implementing ADI activities?

1.5 Abbreviations

ADI	Argument-Driven Inquiry
METU	Middle East Technical University
MSE	Mathematics and Science Education
PPT	Pre-service Physics Teacher
SPS	Science Process Skill
TAP	Toulmin Argument Pattern

CHAPTER 2

LITERATURE REVIEW

This research is grounded in three distinct research domains related to science education and their intersection: Inquiry, argumentation, and ADI. Consequently, the literature review starts by exploring the theoretical foundations of inquiry, argumentation, and ADI separately. Subsequently, it delves into the influence of these three domains on students. Following this, the chapter addresses the challenges encountered by teachers, pre-service teachers, and students when applying these approaches in science classrooms.

2.1 Inquiry, Argumentation, and Argument-Driven Inquiry

This section delves into the theoretical underpinnings of inquiry, argumentation, and ADI in the context of science education. The study draws upon three significant bodies of research, each contributing unique perspectives to the understanding of effective teaching and learning methodologies.

2.1.1 Theoretical Underpinnings of Inquiry

The term "inquiry" has a consistent and enduring history as the principal term employed to characterize effective science teaching and learning. At times, it has been referred to as "inquiry," and alternatively as "enquiry," though both terms have been used interchangeably (Barrow, 2006). The term's roots can be traced back to the 13th century, signifying the act of "seeking information" (Online Etymology Dictionary, n.d.). In the realm of science education, the term "inquiry" is utilized in various contexts, leading to challenges in reaching a unanimous definition among science educators and researchers (Colburn, 2000; Martin-Hauser, 2002). Anderson (2007, p. 808) underscores the necessity for clarity in using the term, stating, "If [inquiry] is to continue to be useful, we will have to press for clarity when the word enters a conversation and not assume we know the intended meaning." (p. 21).

The term "inquiry" has been employed to denote the process of conducting scientific investigations and is commonly associated with the term "scientific inquiry" (NRC, 1996). According to the National Science Education Standards, inquiry is defined as "the diverse ways in which scientists study the natural world and propose explanations based on evidence derived from their work" (NRC, 1996, p. 23). Alternatively, Chinn and Malhotra characterize inquiry simply as the investigations conducted by scientists (2002). These conceptualizations of inquiry not only reveal the evolving nature of scientific practices but also underscore their autonomy from the educational system.

The term "inquiry" is widely used in the context of learning and teaching, manifesting in various forms such as student inquiry, inquiry-based learning, inquiry-based teaching, inquiry-based approach, discovery-based learning, and research-based learning (refer to Barman, 2002; Bruner, 1961; Činčera, 2014; Furtak et al., 2012; Lederman, 2003; Spronken-Smith, 2012). Haury (1993) contends that inquiry necessitates an inherently curious mindset actively seeking answers, and inquiry-based teaching involves students in the investigative aspects of science. The National Science Education Standards (NRC, 1996) define inquiry education as an active learning approach emphasizing questioning, experimental planning, data gathering, analysis, and critical thinking. Barman (2002) proposes that educational inquiry should concentrate on both teaching science process skills, such as observation and data collection, and on learning strategies contributing to science comprehension through investigations. Cairns and Areepattamannil (2019) outline three dimensions of inquiry teaching: (1) teaching of inquiry (imparting science process skills), (2) teaching about inquiry (educating on how scientists employ inquiry-based methods to explore the natural world), and (3) teaching through inquiry (instructing concepts via inquiry). More recently, the National Science Education Standards (NRC, 2000) identified five necessary characteristics of inquiry in learning environments:

1. Scientifically oriented questions to stimulate the students' interest.
2. Evidence collected by learners to enable them to refine their answers to the scientifically oriented question.
3. Explanations that students form based on their evidence to answer scientifically oriented questions.
4. Assessment of their explanations; this assessment may involve alternative explanations that reflect scientific understanding.
5. Communication and justification of suggested explanations.

As per the findings of Jerrim et al. (2022) and Spronken-Smith (2012), science learning through inquiry has involved fostering students' indirect acquisition of scientific knowledge through their investigations. This contrasts with the conventional approach of directly receiving scientific knowledge from teachers. Importantly, this method, characterized by a student-centered approach, has been instrumental in cultivating students as lifelong learners. It has been seen that inquiry-based learning has the theoretical underpinnings of cognitive constructivism where the learner actively constructs knowledge through experience (Bruner, 1960; Piaget, 1972).

This study emphasizes inquiry as a fundamental learning method, encompassing various forms like student inquiry and inquiry-based learning. It promotes an inherently curious mindset, engaging students in scientific investigation and aligning with educational standards. The focus on science process skills and the three dimensions of inquiry teaching underscores its significance. In conclusion, the study concurs with previous findings, emphasizing inquiry's transformative role in fostering scientific knowledge acquisition and cultivating lifelong learners.

In science education, the foundation of inquiry can be traced back to the ideas of pioneers such as Dewey (1910, as cited in Barrow, 2006) and Bruner (1960). Dewey criticized teacher-centric approaches, advocating for inquiry as the primary teaching method. He believed traditional education placed excessive emphasis on facts and lacked the reflection of scientific processes. Dewey proposed a method involving recognizing confusing situations, clarifying problems, formulating temporary hypotheses, testing and revising them, and working through solutions. In Dewey's approach, the teacher played a passive guiding role, offering support and guiding questions, while students actively engaged in learning. Similarly, Bruner (1960) introduced a pedagogical guideline aligning with scientific inquiry, emphasizing that learners should act as scientists for meaningful science learning rather than memorizing teachers' information. In his words, "[t]he schoolboy learning physics is a physicist, and it is easier for him to learn physics behaving like a physicist than doing something else."

It's crucial to highlight that inquiry activities can be designed at various levels. The National Science Education Standards outlined four distinct levels of inquiry activities (NRC, 2000; refer to Table 2.1).

Table 2.1. Inquiry Levels and Their Descriptions

Confirmatory Inquiry	The teacher presents students with a question for investigation along with methods of data collection. Students confirm a principle, law, or fact through an activity where the outcome is predetermined.
Structured Inquiry	The teacher presents students with a question to investigate and provides methods of data collection. The outcome is uncertain, and students are accountable for attaining and interpreting the result.
Guided Inquiry	The teacher presents students with a research question, and students are tasked with choosing or creating their own methods for data collection. They are responsible for anticipating and interpreting the unknown outcome.
Open Inquiry	Students are tasked with formulating questions related to the topic, choosing or creating methods for data collection, and predicting and interpreting the unknown outcome. In essence, students assume responsibility for every aspect of the inquiry process.

2.1.2 Theoretical Underpinnings of Argumentation

Researchers globally have delved into the study of argumentation for numerous decades, resulting in a substantial body of pertinent research. While some have employed the terms “argument” and “argumentation” interchangeably, others have underscored the difference between them (refer to Namdar & Shen, 2016; O’Keefe, 1982; Rieke & Sillars, 1993; Sampson & Clark, 2008; Simon et al., 2006).

Toulmin (1958) introduced an intricate structural model of argumentation in his seminal work, “The Uses of Argument.” Through the analysis of various arguments, he delineated how people naturally engage in argumentation. This analysis led to the formulation of the Toulmin Argument Pattern (TAP), a model that identifies the essential components of an argument and their interrelationships. Widely adopted by educators, particularly in the field of science education, TAP has served as a prevalent template for describing and evaluating students’ arguments in recent years (refer to Christodoulou & Osborne, 2014; Driver et al., 2000; Erduran et al., 2004; Jiménez-Aleixandre et al., 2000; Grooms et al., 2016; Sampson & Clark, 2008; Russell, 1981; von Aufschnaiter et al., 2008).

TAP comprises six elements: Claim, data, warrant, backing, qualifier, and rebuttal. Figure 2.1 illustrates the interrelation of these elements within an argument, accompanied by an example.

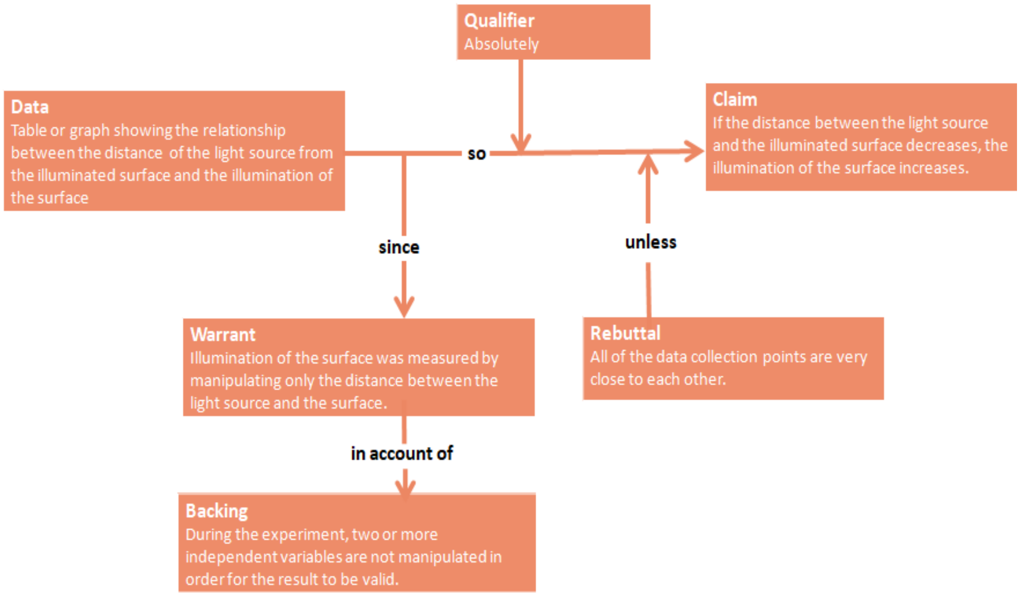


Figure 2.1. Toulmin Argument Pattern

The elements are described below:

Claim: Idea that individuals possess, an assertion they present, or a conclusion they arrive at. This constitutes the principal element of the pattern.

Data: Information, fact, or process utilized as proof to substantiate the claim.

Warrant: A bridge linking the data to the claim, elucidating the manner in which and the reasons why the data supports the claim.

Backing: Justification exposing why the warrant is relevant, reinforcing both the warrant and, consequently, the claim.

Rebuttal: Statement that contradicts any element of the argument.

Qualifier: Expression that outlines the limits of the claim, specifying the situations in which the claim holds true (e.g., mostly, certainly, possibly).

O'Keefe (1982) defines argument as a product consisting of a conclusion derived from premises. Rieke and Sillars (1993) describe it as the conjunction of a claim with its grounds, the supporting elements. Simon et al. (2006) characterize argument as a combination of elements, including claim, data, warrant, and backing. Sampson and Clark (2008) offer a simple definition as "artifacts students create to articulate and justify claims or explanations". Besnard and Hunter (2008) see it as a set comprising a conclusion (claim) and its supports (assumptions or premises) providing justification. A simplified Toulmin Argument Pattern (TAP) model, involving claim, evidence, and reasoning, has gained popularity among researchers and science educators (Berland & Reiser, 2009; Grooms et al., 2016; McNeill & Krajcik, 2007). This study utilizes TAP for a detailed analysis of challenges faced by PPTs.

Argumentation has been characterized diversely as the act of forming and/or expressing arguments in written or verbal form and/or engaging in discussions to persuade or establish a consensus. Sampson and Clark (2008) define argumentation as an intricate process where students create artifacts to formulate and support claims. Similarly, Jiménez-Aleixandre and Erduran (2008) depict argumentation as the connection between data and claims through the justification and evaluation of knowledge.

A number of studies have taken a different position and defined argumentation as the construction of a reckoning. Argumentation has been seen as a dialogical process to influence people's minds by providing, supporting, and modifying one's own claims and critiquing those of others (Berland & Reiser, 2009, 2011; Duschl & Osborne, 2002; Golanics & Nussbaum, 2008; O'Keefe, 1982; Rieke & Sillars, 1993). Simon et al. (2006) straightforwardly equate argumentation with the act of arguing. Duschl et al. (2007, p. 33) articulate argumentation as "a mode of logical discourse whose goal is to tease out the relationship between ideas and evidence" in their influential book, "Taking Science to School: Teaching Science in Grades K-8". Besnard and Hunter (2008) and Costello and Mitchell (1995) have described the argumentation process as the construction, comparison, and evaluation of the arguments by integrating the construction and discussion processes.

In a more expansive sense, "argumentation is a verbal, social, and rational activity aimed at formulating a reasoned critique of the acceptability of a standpoint by presenting a constellation of proposals, justifications, or refutations related to the proposition expressed in the standpoint" (van Eemeren & Grootendorst, 2004, p.1). This involves individuals constructing claims, offering justifications, expressing their viewpoints, and evaluating others' claims and justifications within the context of argumentation (Driver et al., 2000). Namdar and Shen (2012) suggest that argumentation can be viewed as a combination of three distinct processes: (1) linguistic processes involving verbal and written arguments, (2) cognitive processes involving reasoning during discussions, and (3) social processes involving interactions among arguers. Duschl and Osborn (2002) have stressed that argumentation is a critical discourse process in which it has conceptual and epistemic goals of science.

The researcher's view aligns with varied definitions of argumentation, encompassing diverse forms of expressing arguments and engaging in discussions for persuasion or consensus. Argumentation involves constructing and supporting claims, dialogical processes, and a rational critique of standpoints through proposals, justifications, and refutations, with linguistic, cognitive, and social dimensions.

Kuhn (2010) underscores the significance of learners' argumentation skills as crucial intellectual abilities. Argumentation is defined as the collective engagement of numerous individuals in a reasoning process (van Eemeren et al., 1996; Yeh & She, 2010), and it takes place within purposeful dialogues where reasoning is involved (Walton, 2006).

Aydeniz et al. (2012) characterize argumentation within educational settings as a pedagogy aligned with reform, incorporating epistemological elements from cognitive approaches such as social constructivism. Social constructivism posits that learning involves the collaborative construction of knowledge through communicative and social processes (Aldridge et al., 2000; Driver et al., 1994; Vygotsky, 1978).

2.1.3 Argument-Driven Inquiry

ADI represents an instructional approach integrating inquiry and argumentation within educational settings (Walker et al., 2011). This method offers a laboratory-based model that facilitates argumentative discussions within teams and between different teams (Grooms et al., 2018; Walker et al., 2016). Grooms et al. (2016) outlined the eight stages of ADI, as presented in Table 2.2.

Table 2.2. ADI stages and their descriptions

ADI Stages	Description
Stage 1 Identification of the Task and the Research Question	The teacher presents the research question, introduces the topic, and guides the investigation. Like other approaches such as the Learning Cycle, this stage involves capturing students' interests, connecting past and current experiences, and clarifying the objectives of upcoming activities.
Stage 2 Develop a Method and then Collect and Analyze Data	It centers on the creation and examination of data. During this phase, students collaborate in groups of three or four to devise and execute their own approach to address the research question.
Stage 3 Develop a Tentative Argument	Students formulate a provisional argument, comprising a claim (conclusion, explanation, and descriptive statement), evidence (measurements, observations), and a justification (an explanation of why the evidence supports the claim) in response to the research question.

Table 2.2 (Continued)

Stage 4 Argumentation Session	Students present their arguments to peers and provide critiques of others' arguments. Following the session, all groups have a chance to refine their arguments. This stage aims to teach students the skills of sharing and critiquing.
Stage 5 Explicit and Reflective Discussion	This involves a teacher-led whole-class discussion where students share their knowledge and discuss crosscutting concepts, the nature of science, and scientific inquiry.
Stage 6 Write an Investigation Report	Individually, students compose an investigation report containing the aim, method, and argument, promoting metacognition through this process.
Stage 7 Double Blind Group Peer Review	In this phase, each group conducts blind reviews of multiple reports for feedback, enabling students to develop evaluation skills.
Stage 8 Revises and Submits Report to the Instructor	Following the revision prompted by the double-blind group peer review, students submit their report to the teacher.

2.2 Student Outcomes of Inquiry, Argumentation, and Argument-Driven Inquiry

The subsequent pages present findings from relevant studies showcasing the efficacy of inquiry, argumentation, and ADI, recognized as significant contemporary trends in science education reform.

2.2.1 Student Outcomes of Inquiry in Science Education

The subsequent sections delve into the impact of inquiry on students' science learning, scientific skills, epistemological understanding, affective factors, and the potential factors contributing to conflicting outcomes in the inquiry literature.

2.2.1.1 Effect of Inquiry on Students' Science Learning

Mattheis and Nakayama (1988) found that a laboratory-based inquiry curriculum did not yield a substantial impact on the science comprehension of middle school students when compared to those utilizing a traditional text-based curriculum. Conversely, Klahr and Nigam (2004) established the superiority of direct instruction over inquiry-based learning in science education, particularly evident in their study involving elementary school students. The efficacy of inquiry-based learning may have been compromised, as suggested by Klahr and Nigam (2004), due to the novice or low-achieving status of the students. Unexpectedly, Borman et al. (2008) reported a significant decline in the academic achievement of elementary school students following exposure to inquiry-based learning. Cairns and Areepattamannil (2019) conducted an analysis using data from the Program for International Student Assessment 2006 (PISA 2006) to explore the correlation between inquiry-based science education and the science achievement of high school students. Their findings indicated a significant negative relationship between the teaching method and science achievement.

Numerous studies within the inquiry literature have reported either negative or negligible effects on student science learning. However, a substantial body of research overwhelmingly demonstrates the positive impact of inquiry-based science curricula on student learning. Shymansky et al. (1983) conducted a comprehensive review, summarizing 105 experimental studies on the effects of inquiry-based science curricula, revealing that students engaged in such curricula exhibited greater improvements in science learning compared to those in traditional settings. Minner et al. (2010) synthesized findings from 138 studies between 1984 and 2002, emphasizing that inquiry-based learning actively engaging K-12 students is more effective in increasing conceptual understanding than passive methods. In a recent meta-analysis, Furtak et al.'s (2012) meta-analysis of studies between 1996 and 2006 reinforced the positive effects of guided inquiry learning over traditional instruction.

Marx et al. (2004) contributed to these evidences through a three-year longitudinal study, highlighting significant gains in science achievement for urban students in sixth to eighth grades participating in inquiry-based science lessons. This study notably dispels the notion that urban students identified as low achievers can thrive with the careful implementation of an inquiry curriculum. Tuan et al. (2005) affirmed the positive influence of inquiry instruction, attributing improved science learning to heightened student motivation. Dean and Kuhn (2007) replicated the small, short-term study of Klahr and Nigam (2004) by focusing on students of the same age and similar characteristics as the sample of Klahr and Nigam (2004). Dean and Kuhn followed the students for 10 weeks, unlike the Klahr and Nigam study. In conclusion, the researchers invalidated the conclusion that direct instruction is superior to inquiry-based learning for science learning. Blanchard et al. (2010) reported significantly higher growth and persistence in science learning among middle and high school students participating in guided inquiry-based instruction compared to traditional laboratory-based instruction. Fang et al. (2016) observed promising effects of inquiry on high school students' science learning, while Constantinou et al. (2018) emphasized the enhanced understanding of science concepts and principles in inquiry learning environments. Summerlee and Murray (2010) further supported these findings, revealing improved academic performance and advanced resource utilization among university students engaged in inquiry.

2.2.1.2 Effect of Inquiry on Students' Scientific Skills

McConney et al. (2014) illustrated that adolescents in high school who were exposed to increased levels of inquiry-based activities exhibited diminished levels of science literacy, encompassing skills in scientific processes, as indicated by their analysis of PISA 2006 science data.

Regarding the positive impacts of inquiry, there is a notably higher prevalence of favorable outcomes on students' scientific skills compared to negative effects. Mattheis and Nakayama (1988) highlighted that middle school students enhanced their scientific process skills, such as interpreting data and graphing, through inquiry-based learning in the Foundational Approaches in Science Teaching (FAST) program. Fang et al. (2016) observed significant improvement in the experimental skills of high school students through inquiry-based learning. Shymansky et al. (1983) reported that students engaged in inquiry outperformed their counterparts in analytical skills, scientific process skills, and communication skills in comparison to traditional learning environments. Constantinou et al. (2018) stressed the development of inquiry skills, critical thinking, decision-making, problem-solving, and scientific reasoning within an inquiry context. Cuevas et al. (2005) demonstrated that inquiry-based learning heightened scientific process skills in elementary school students, particularly in planning and drawing conclusions. Additionally, Gibson and Chase (2002) found that inquiry learning enhanced the social skills of middle and high school students due to the collaborative nature of the approach.

2.2.1.3 Effect of Inquiry on Students' Epistemological Understanding

In its inherent nature, inquiry contributes to the development of epistemological understanding, encompassing explanation procedures and causal relations, and extends to the comprehension of the Nature of Science (NOS). Research on students' epistemological ideas in science education emerged under the name of NOS research (Sadler, 2004; Sandoval & Millwood, 2008). NRC (2000) and Abrams et al. (2008) emphasized that inquiry has achieved learning about inquiry, which is an understanding of how scientific inquiry has progressed in addition to all other contributions to students.

Chinn and Malhotra (2002) outlined in their framework that inquiry activities cultivate students' awareness of the epistemological evolution of science. Constantinou et al. (2018) elucidated that inquiry shapes students' epistemological understanding by involving them in the various stages of scientific inquiry, including formulating hypotheses, planning and conducting investigations, analyzing data, interpreting results, constructing explanations, and engaging in argumentation. The researchers emphasized that students immersed in an inquiry environment enhance their awareness of the nature of science, encompassing scientific reasoning, communication, and understanding of scientific achievements. Ultimately, drawing on Furtak et al.'s (2012) meta-analysis, it is affirmed that students achieve superior learning outcomes through inquiry as they actively engage in the epistemic domain of inquiry.

2.2.1.4 Effect of Inquiry on Students' Affective Factors

In their comprehensive analysis, Shymansky et al. (1983) discovered that exposure to inquiry-based science curricula led to an enhancement in students' favorable attitudes toward science. Investigating the enduring impacts of inquiry-based education, Gibson and Chase (2002) delved into the Summer Science Exploration Program (SSEP), a science camp. Their findings revealed that SSEP not only elevated attitudes toward science and interest in science careers among randomly selected middle and high school students but also indicated that these positive effects endured over the years. Tuan et al. (2005) observed heightened motivation toward science learning among eighth-grade students who engaged in inquiry-based science education, in contrast to those exposed to traditional instruction. Palmer (2009) concluded that inquiry serves as an effective learning method for cultivating situational interest and short-term motivation in ninth-grade students during science classes.

Highlighting the impact on preschool students, Patrick et al. (2009) demonstrated that participation in the Scientific Literacy Project (SLP), incorporating scientific inquiry and literacy activities, significantly increased motivation compared to traditional science experiences. Spronken-Smith (2012) argued that students can derive high motivation from intricate, self-relevant questions posed in the context of inquiry learning. Analyzing PISA 2006 science data, McConney et al. (2014) found that high school students engaged in extensive inquiry activities exhibited heightened levels of both engagement in science and interest in learning science. Constantinou et al. (2018) underscored the improvement in students' motivation and positive attitudes toward science within the framework of inquiry. Additionally, Cairns and Areepattamannil (2019) substantiated a significant positive correlation between inquiry-based teaching and dispositions toward science, including self-efficacy, science motivation, and interest in science learning, based on their analysis using data from PISA 2006.

2.2.1.5 Possible Reasons for the Conflicting Results in the Inquiry Literature

As evident, discrepancies exist in the findings of studies within the inquiry literature, and these inconsistencies might be attributed to various potential factors, outlined below:

1. Numerous factors must be taken into account when introducing inquiry-based learning in an educational setting. These encompass aspects such as the content's nature, time constraints, available materials, students' abilities, and their prior knowledge (Abrams et al., 2007).
2. The demand for advanced inquiry skills and knowledge in the inquiry process has led to cognitive overload, hindering students from comprehending essential concepts (Kirschner et al., 2006). In their own words, Kirschner et al. describe this scenario, stating, "The benefit of guidance diminishes only when learners possess adequate prior knowledge to offer 'internal' guidance."
3. Bell et al. (2005) and Jiang and McComas (2015) explained that the inconsistency in results was linked to the extent of inquiry application. The researchers emphasized that diminishing guidance does not automatically enhance student learning. They suggested viewing the inquiry rubric as a gradual advancement, cautioning against perceiving open inquiry as an initial stage. They proposed that students commence at a level aligning with their knowledge and skills, allowing them to practice inquiry systematically, progressing through intricate levels with essential scaffolding.

4. According to Teig et al. (2018), these inconsistencies could be associated with the analysis of data and the type of measure used for assessing inquiry learning. For example, assessing the effectiveness of inquiry-based learning in science education often involves measuring the frequency of inquiry activities (e.g., Stohr-Hunt, 1996).

2.2.2 Student Outcomes of Argumentation in Science Education

The following sections explore how argumentation influences students' learning of science, their scientific skills, their epistemological understandings, and their affective factors.

2.2.2.1 Effect of Argumentation on Students' Science Learning

Argumentation played a pivotal role in the learning process, as highlighted by Kelly and Chen (1999). Mason (1996, 1998) illustrated that fifth-grade students developed a profound understanding of new concepts through reasoning and argumentation. Bell and Lin (2000) noted a transition from procedural to conceptual exploration among middle school students engaged in argumentation activities, emphasizing its role in facilitating knowledge integration. Zohar and Nemet's (2002) experimental study revealed that junior high school students in the argumentation group exhibited a more significant increase in achievement compared to the comparison group, suggesting that argumentative discussions enhanced the integration of prior and new knowledge.

Andriessen (2006) and Bathgate et al. (2015) separately contended that argumentation activities contributed to deeper learning by involving reasoning, elaboration, reflection, and evidence evaluation. von Aufschnaiter et al. (2008) explored the link between cognitive development and argumentation processes in junior high school students during science and socio-scientific lessons, finding that students paid attention to and utilized prior knowledge, leading to improved science understanding. Venville and Dawson's (2010) experimental study indicated that high school students engaging in argumentation showed enhanced conceptual understanding. Ogan-Bekiroglu and Aydeniz (2013) reported positive attitudes of pre-service physics teachers towards argumentation-based learning, emphasizing its potential for meaningful learning. Bathgate et al. (2015) demonstrated a positive impact of argumentation on the learning of middle school students engaged in inquiry science. Kutluca and Aydin's (2016) findings indicated that pre-service elementary science teachers believed that argumentation facilitated meaningful learning. Additionally, Kola (2017) discovered that pre-service physics teachers achieved deeper learning through dialectical argumentation.

Asterhan and Schwarz (2007) illustrated that undergraduate students exhibited enhanced learning and sustained these improvements over time. Similarly, as noted by Nussbaum (2008), argumentation could exert lasting effects in fortifying learning outcomes.

Baker (1999) suggests that argumentation has the potential to deeply engage students and serve as a means of refuting misconceptions. Nussbaum and Sinatra (2003) provided evidence, indicating that undergraduate students, through argumentation, could facilitate conceptual change. Classroom implementation of argumentation offered students the chance to validate their existing knowledge and construct new knowledge through interactions with their peers, aiding in the correction of misconceptions (Cross et al., 2008). Asterhan and Schwarz (2009) discovered that heightened epistemic effects resulted in conceptual changes, thereby enhancing content learning in undergraduate students. Yeh and She (2010) demonstrated that eighth graders in an online argumentation group outperformed their counterparts who studied online without argumentation, suggesting that argumentation played a pivotal role in fostering students' conceptions and conceptual changes.

In her research, Mason (2001) observed that fourth graders not only progressed conceptually but also enhanced their metaconceptual awareness by engaging in argumentative discourse. Jiménez-Aleixandre and Erduran (2008) clarified that the construction of knowledge in science is intricately linked to justifying knowledge, where claims are supported by a logical reasoning path or evidence from diverse sources. Additionally, they highlighted that when students participated in reasoned discourse, they were involved in metacognitive processes, specifically reasoning about their own reasoning.

2.2.2.2 Effect of Argumentation on Students' Scientific Skills

Bell and Linn (2000) and Kuhn (2010), in separate studies conducted at different time points, demonstrated that middle school students enhanced their argumentation skills through exposure to argumentative discourse. High school students, as revealed by Jiménez-Aleixandre et al. (2000), developed their argumentation skills. In the initial phases of the intervention, their arguments included conclusions supported by data and evidence, evolving into more sophisticated forms in later episodes that incorporated justifications and backings. Kutluca and Aydin (2016) obtained analogous results in their study involving pre-service elementary science teachers, where arguments progressed from claim and data to encompass claim, data, justification, and backing. Zohar and Nemet's (2002) experimental study with junior high school students showed that students in the argumentation group produced higher-quality arguments in the post-test compared to those in the comparison group. Kuhn and Udell (2003) illustrated that academically at-risk middle school students exhibited the improved quality of arguments, discourse quality, and the quantity of reasons used through increased engagement in argumentative discourse activities. Osborne et al. (2004a) conducted a study to promote argumentation in school science classrooms, and the results indicated significant development in both teachers' and junior high school students' argumentation quality. Martin and Hand (2009) noted an augmentation in middle school students' use of terminology such as claims, evidence, and evaluation of classmates' arguments. Venville and Dawson's (2010) study demonstrated that high school students learning through argumentation significantly improved their argument quality and reasoning skills. Grooms et al. (2014), through an experimental study on undergraduate students, found that those in the argument-based instruction group generated notably better arguments than the comparison group.

Argumentation serves as a vital instrument for cultivating reasoning skills (Andriessen, 2006; Baker, 2009), critical thinking skills (Bathgate et al., 2015; Duschl & Osborne, 2002; Nussbaum & Edwards, 2011), and social skills (Osborne et al., 2004b). According to Nussbaum (2008), students needed to be taught reasoning skills and this need led to an increased interest in argumentation. Goldstein et al. (2009) showed that middle school students improved their critical thinking skills by refuting peers' arguments with significant counterarguments during a year-long intervention.

2.2.2.3 Effect of Argumentation on Students' Epistemological Understanding

The enhancement of epistemic understanding is inherent in argumentation, as highlighted by Duschl (2008) and Jiménes-Aleixandre & Erduran (2008). This is particularly significant because argumentation stands as a fundamental epistemic practice in the field of science, as asserted by Bricker & Bell (2008). Newton et al. (1999) emphasized that student participation in argumentation activities involves a meaningful engagement with the epistemological foundations of science. Similarly, Bell and Linn (2000) observed that involvement in argumentation activities led students to refine their perceptions of science, recognizing that scientific inquiry encompasses not only observation and description but also creative and warranting acts.

Beyond acquiring scientific concepts, students must also develop an understanding of the epistemology, scientific methods, and socially constructed nature of science, as noted by Driver et al. (2000). Erduran and Msimanga (2004) asserted that arguments play a critical role in advancing the discipline's epistemological knowledge by facilitating knowledge building and engaging in a dialectical critique process to warrant the claims of others. Kelly (2007) defined epistemic practices as specific ways of proposing, justifying, evaluating, and legitimizing knowledge claims within a framework.

In Sandoval and Millwood's (2008) study, students who participated in argumentation demonstrated an understanding of the norms of argumentation, leading to a deeper epistemological understanding of science. Ryu and Sandoval (2012) discovered that elementary students in third and fourth grades experienced improvements in their epistemic understanding through learning how to use evidence in constructing their arguments and evaluating others' arguments. Additionally, these students exhibited enhanced skills in justification.

2.2.2.4 Effect of Argumentation on Students' Affective Factors

Engagement in argumentation has been shown to positively influence students' attitudes (Kutluca & Aydın, 2016), motivation (Bell & Linn, 2000; Chinn, 2006), and self-efficacy (Aydeniz & Ozdilek, 2016). Ogan-Bekiroglu and Aydeniz (2013), in their study involving pre-service physics teachers, reported an increase in participants' motivation to teach science. The findings of both Ogan-Bekiroglu and Aydeniz (2013) and Aydeniz and Ozdilek (2016) demonstrated that incorporating argumentation-based pedagogy offered diverse learning opportunities for learners and heightened their interest in participating in science lessons. Consequently, argumentation positively affected the self-efficacy of pre-service physics teachers in teaching science. According to Kutluca and Aydin (2016), engagement in socio-scientific argumentation led to an improvement in the attitudes of pre-service elementary science teachers towards science education. The researcher of this study did not find any studies indicating negative or no effects of argumentation on students.

2.2.3 Student Outcomes of Argument-Driven Inquiry in Science Education

The upcoming sections delve into the impact of ADI on students' acquisition of scientific knowledge, their development of scientific skills, and the influencing factors on their emotional responses to the learning process.

2.2.3.1 Effect of Argument-Driven Inquiry on Students' Science Learning

Sampson et al. (2013) conducted a study utilizing ADI to assess the conceptual understanding of middle and high school students. The study's findings revealed that students experienced substantial improvements in conceptual understanding throughout the intervention. Similarly, Walker et al. (2016) explored the impact of ADI on the academic performance of college students and discovered that those in the ADI class exhibited higher achievement compared to their counterparts in the traditional lab class. This disparity was attributed to the increased opportunities for students in the ADI class to engage in discussions about fundamental concepts and integrate them with scientific practices for explaining phenomena and solving scientific problems. Conversely, Walker et al. (2012) did not observe a noteworthy enhancement in the conceptual understanding of undergraduate students enrolled in an ADI class.

2.2.3.2 Effect of Argument-Driven Inquiry on Students' Scientific Skills

Sampson et al. (2011) explored the impact of a series of laboratory activities designed with ADI on elementary students' engagement in argumentation and the quality of their arguments. The study's findings indicated that students' participation in argumentation became more structured, leading to an improvement in the quality of their arguments over time. In a study by Walker et al. (2012), an experimental approach was employed where one group received ADI instruction, while the other received traditional instruction. The results revealed that students in the ADI group significantly enhanced their argumentation skills compared to those taught with traditional methods. Notably, there was a significant difference observed in the utilization of evidence and reasoning.

Walker and Sampson (2013a) investigated the development of undergraduate students' participation in argumentation sessions within a laboratory course designed with ADI. Their analysis indicated a significant improvement in the quality of students' argumentation, both orally and in written form. Songsil et al. (2019) conducted a study using a revised version of ADI, known as revised Argument-Driven Inquiry (rADI) and found that high school students improved their argumentation skills through instruction designed with the rADI method. Admoko et al. (2021) reported that the ADI learning method contributed to the development of argumentation skills in high school students, aligning with the findings of their study.

Hosbein et al. (2021) tracked the argumentation of undergraduate students in two chemistry courses designed with ADI, examining changes in cognitive, epistemic, and social aspects of argumentation. While no significant differences were found in these three aspects individually, all aspects showed a significant overall improvement. In essence, the overall quality of argumentation within the learning environment increased.

In terms of skills, the impact of ADI on writing skills is noteworthy. Sampson and Walker (2012) conducted an examination of undergraduate students' writing skills, encompassing the quality of arguments, content knowledge, and engagement in the peer-review process while studying science through ADI. Their findings indicated that students provided more feedback on lower-scoring draft reports and less feedback on higher-scoring draft reports. Moreover, over time, students' scores in the double-blind peer review process became more aligned with the researchers' scores. These observations suggested an improvement in the quality of both the initial and revised reports throughout the implementation of ADI.

In a study by Sampson et al. (2013) involving middle and high school students, it was found that students who learned science through ADI made significant advancements in argumentative writing skills during the intervention. Additionally, Walker and Sampson (2013b) demonstrated that undergraduate students experienced substantial improvements in both their writing skills and their ability to evaluate their peers' writings in a laboratory course instructed using ADI.

2.2.3.3 Effect of Argument-Driven Inquiry on Students' Affective Factors

Walker et al. (2012) found that students' inclination toward science witnessed a positive upswing when they actively participated in ADI. In the current study, the researcher identified only one investigation that explored the impact of ADI on the affective domain of students. The relative scarcity of attention given to assessing the influence of a practice integral to science education is somewhat perplexing.

2.3 Challenges with Inquiry, Argumentation and Argument-Driven Inquiry

Given the numerous advantages associated with inquiry, argumentation, and ADI, one would anticipate their widespread presence in learning settings. Regrettably, these approaches are seldom observed in science teaching environments, as noted by Anderson (2002) and Driver et al. (2000). The reluctance to adopt these methods can be attributed to the challenges encountered by both teachers and students in implementing and learning through inquiry, argumentation, and ADI. Various challenges have been identified through existing studies, and these challenges are outlined below.

2.3.1 Challenges with Inquiry

Roehrig and Luft (2004) conducted a year-long study tracking novice secondary science teachers to investigate the limitations influencing their implementation of inquiry-based teaching. Through case and cross-case comparisons, the researchers identified five primary constraints. These included deficiencies in science content knowledge, pedagogy content knowledge, understanding the nature of science and scientific inquiry, teachers' beliefs regarding teaching through inquiry, and apprehensions related to classroom management.

Yoon et al. (2012) explored the perceptions and execution of inquiry-based teaching by pre-service elementary teachers during their teaching experiences and the obstacles encountered in the process. The study revealed that these pre-service teachers encountered challenges in (1) fostering the development of students' ideas and maintaining their interest, (2) guiding students in the establishment of valid and reliable experiments to test hypotheses, and (3) aiding students in the processes of data analysis and discussion. These difficulties were attributed to the pre-service teachers' inadequacies in science content knowledge and pedagogy content knowledge.

Duggan et al. (1996) reported that 12-14 year old students experienced complexity in defining the dependent variable and controlling variables in their investigative work on defining variables.

Krajcik et al. (1998) explored the challenges faced by middle school students in their initial exposure to inquiry-based learning. The outcomes of the conducted case studies revealed that the students encountered challenges in planning procedures and formulating investigations. Specifically, they struggled with tasks such as controlling variables, emphasizing the scientific significance of posed questions, as well as collecting, analyzing, and drawing conclusions from data.

Edelson et al. (1999) investigated the impediments to the effective implementation of inquiry-based learning, which undermine the process of science learning, and identified five significant challenges. Firstly, motivating and capturing students' interest in the subject matter was identified as a primary challenge. In the absence of sufficient motivation, students would likely struggle or be hesitant to engage in inquiry activities. Secondly, there was a challenge concerning students' proficiency in scientific investigation techniques, including data collection and analysis. Without a grasp of these techniques, students might refrain from conducting investigations.

Thirdly, insufficient background knowledge posed a challenge, as students with a lack of foundational knowledge would find it difficult to develop research plans and undertake tasks such as data collection, analysis, and interpretation. The fourth challenge involved students managing complex, extended activities. Without proper organization and management, students might not fully benefit from the potential of inquiry-based learning. The fifth challenge was the inadequacy of resources. It was crucial for inquiry-based learning technologies and activities to align with the practical limitations of the learning context, considering factors such as existing resources and rigid schedules. Failure to adapt to available technology or align with the school's existing program could lead to the failure of the instructional design.

In his comprehensive analysis of inquiry-based learning, Anderson (2002) pinpointed three challenging dilemmas that impede the successful implementation of this approach in science classrooms. Firstly, technical dilemmas encompassed issues such as the lack of skills for effective teaching, the level of commitment to textbooks, challenges associated with national assessments, difficulties in executing group work, challenges in adapting to new roles (teacher as a guide, student as an active learner), and insufficient professional development programs. Secondly, policy dilemmas involved short-term or limited professional development initiatives, resistance from parents regarding science education beyond their own experiences, conflicts among science teachers regarding curriculum and teaching methodologies, a shortage of available resources, and diverse opinions on equity and fairness. Thirdly, cultural dilemmas included concerns about the quality of textbooks, perspectives on assessment goals, and considerations about preparation for upcoming science classes. Anderson underscored that the difficulty of preparing teachers for inquiry-based learning surpassed the technical obstacles associated with teaching itself.

Castro and Morales (2017) outlined the difficulties encountered by elementary school students participating in guided inquiry activities. According to their findings, students faced challenges in several areas: (1) acquiring sufficient background knowledge, (2) formulating experiments aligned with the research question, incorporating relevant materials, establishing a logical procedure, and considering variables, (3) executing laboratory procedures like measuring volume and utilizing a microscope, (4) managing extended activities such as group meetings, and (5) composing an experimental report with clear objectives, a well-structured theoretical background, a systematic experimental methodology, appropriately labeled tables and figures, a well-organized conclusion and recommendation, and free from typographical and grammatical errors.

2.3.2 Challenges with Argumentation

Newton et al. (1999) conducted interviews with 14 experienced science teachers to explore the factors influencing the reluctance to adopt argumentation-based pedagogy in their classrooms, and they reported their findings. The primary reason identified was the constraint of limited time, attributable to the curriculum being heavily focused on content. Additionally, teachers' limitations in pedagogical knowledge, skills, and epistemological understanding contributed to a lack of confidence. Challenges arose when discussions faced difficulties, making it challenging for teachers to maintain discipline and motivation. Another obstacle was the inadequacy of published materials, such as classroom books, which lacked sufficient guidance on facilitating discussions. Teachers further noted that students exhibited resistance to discussions, expressing a preference for following the course book.

Sampson and Blanchard (2012) examined the impact of introducing argumentation in science classrooms on students' comprehension of concepts and scientific processes. In their study, the researchers conducted interviews with secondary science teachers. Alongside their primary investigation, the researchers inquired during the interviews about the reasons behind teachers' reluctance to incorporate argumentation into their classrooms. The findings highlighted the challenges associated with integrating argumentation into science instruction. According to the researchers, teachers struggled with presenting data and reasoning effectively. Many teachers perceived the incorporation of argumentation as time-consuming, faced challenges due to students' inadequate background knowledge, encountered limitations in resources, and lacked knowledge on how to effectively involve students in argumentation.

Zembal-Saul et al. (2002) examined how pre-service science teachers (PPTs) constructed evidence-based arguments using software. The study's findings indicated that while the arguments were backed by evidence, PPTs encountered challenges in constructing a more intricate form of argument, specifically justification, in contrast to their use of evidence.

Aydeniz and Ozdilek (2016) explored the challenges faced by PPTs and their students during the implementation of argumentation, as well as the solutions proposed by the PPTs. The investigation into difficulties and solutions involved analyzing responses to open-ended questions in a questionnaire provided to the PPTs. The study revealed that PPTs encountered challenges in (1) guiding their students in constructing arguments, (2) assessing students' arguments, particularly evidence and reasoning, (3) managing the timing of instruction, and (4) handling classroom management. On the other hand, the students of PPTs faced difficulties in constructing arguments due to (1) a lack of understanding of what argumentation entails and how it functions, (2) conceptual comprehension challenges, and (3) struggles in using evidence, reasoning, and rebuttal. The PPTs proposed several solutions to address these challenges, including (1) enhancing students' conceptual understanding, (2) increasing the frequency of argumentation activities in the classroom, (3) encouraging students to research the topic of argumentation before engaging in it, and (4) capturing students' attention through intriguing argumentation cases.

In a paper by Kelly et al. (1998), the authors detailed methodological procedures that integrated various perspectives, spanning from the normative viewpoint of philosophy to the naturalistic lens of sociolinguistics, to analyze students' arguments.

The outcomes revealed that high school students formulated arguments without incorporating warrants.

Kelly and Chen (1999) investigated the discourse processes of high school students and identified that, during the implementation, certain students persisted in making claims without providing substantial evidence.

In their study explaining the limited emphasis on argumentation in science education, Driver et al. (2000) noted that the primary obstacles to involving students in argumentation were the inadequate pedagogical skills and knowledge of teachers, as well as a lack of resources to assist teachers in facilitating argumentation in learning settings.

Sandoval (2003) investigated the perspectives of high school students regarding the Nature of Science (NOS), their views on epistemology, and the interplay of these perspectives with conceptual understanding. The analysis of the findings also showed that students struggled to provide supporting data for their claims.

Lizotte et al. (2003) created evaluation criteria while in the process of crafting science curriculum materials. Specifically, they concentrated on assessing what they termed students' explanations, consisting of claim, evidence, and reasoning components. Upon analyzing the students' explanations using the newly devised assessment tools, they observed that middle school students encountered challenges in proposing reasoning.

Sadler (2004) underscored the difficulties faced by students learning science through argumentation activities, drawing insights from the analysis of argument patterns in previous studies by Kortland (1996) and Jiménez-Aleixandre et al. (2000). According to Sadler, middle school students in Kortland's research predominantly presented arguments with direct support for their claims, lacking counterclaims or rebuttals. Kortland hypothesized that the fundamental issues underlying these argument patterns were students' unfamiliarity with constructing arguments and their insufficient knowledge about the topic. Despite implementing ten interventions, each lasting 45 minutes, to address these challenges, Kortland observed minimal improvement in the students' basic-level arguments. Sadler highlighted that, in the study by Jiménez-Aleixandre et al., high school students engaged in discussions at varying levels of argument quality, ranging from naive to sophisticated. Naive arguments lacked data, support, or backing, while sophisticated arguments incorporated justifications and backing. The researchers also noted a lack of qualifiers or rebuttals in students' arguments. Sadler concluded that students encountered challenges in providing adequate justification and necessary rebuttals.

Sandoval and Millwood (2005) conducted a study aiming to explore the connection between the conceptual understanding and epistemological understanding of argumentation in high school students. The results revealed that students encountered difficulties in providing ample evidence to substantiate their claims.

McNeill et al. (2006) investigated the impact of scaffolding on the written explanations of middle school students, using the term "explanation" instead of "argumentation" as utilized by Lizotte et al. (2003). The findings suggested that all students, particularly those who received additional scaffolding during the investigation, encountered challenges with the argumentation component.

Abi-El-Mona and Abd-El-Khalick (2006) recognized the argument structures and schemes employed by high school students. As per their findings, the scholars noted that students' argument structures lack completeness, particularly concerning warrants.

McNeill (2009) conducted a study concentrating on the utilization of argumentation by teachers in science classrooms. The findings revealed that high school students faced challenges with the reasoning component of their arguments.

Berland and Reiser (2011) investigated the argumentative discussions among middle school students in science classrooms to ascertain whether the objectives of the arguments were centered on sensemaking or persuasion. Their analyses uncovered two challenges associated with these objectives. Firstly, students infrequently altered or refined their arguments when faced with refutation, opting to review the evidence instead of revising their initial claims. Secondly, students encountered difficulty in concurrently pursuing goals of sensemaking and persuasion. Some students excelled at individual sensemaking, while others were more proficient at persuading others.

Osborne et al. (2013) conveyed that instructing high school students through argumentation posed challenges for both students and teachers. Students struggled to articulate arguments, hindered by a limited vocabulary and a lack of conceptual understanding of the subject. The simultaneous learning of science content and the epistemology of science proved complex for students. Teachers faced challenges in classroom management when lacking confidence in teaching, and guiding argumentative discussions and managing timing proved to be confusing for them.

Lazarou et al. (2016) conducted a study to demonstrate the utility of argumentation not only as a collaborative endeavor but also as a systematic activity in primary science education. Their findings also brought to light substantial challenges faced by students in engaging in argumentation activities. As per the results, students' arguments were deemed insufficient, limited, and simplistic. This deficiency arose from their inability to substantiate claims with adequate reasons, and when they did provide support, the reasons were deemed inadequate. The students encountered difficulty expressing their thoughts, particularly in the scientific domain, due to unfamiliarity with scientific terms. Even when using familiar terms, articulation remained challenging. Furthermore, language proficiency posed an additional hurdle, as students struggled with formal language use. The family environment played a role, in influencing students' expression; those who did not express themselves at home tended to exhibit similar behavior in the classroom. Insufficient content knowledge also contributed to the challenges, as profound understanding was required to construct complete arguments. Additionally, the nature of the lesson posed a challenge, as students found it difficult to comprehend how to connect systematic argumentation activities. Finally, students' lack of interest in argumentation activities was identified as a contributing factor. The researchers also noted that teachers, burdened by heavy workloads, limited time, and the demands of the curriculum and textbooks, did not employ suitable methods conducive to the development of students' argumentation skills, relying instead on typical activities and questions and answers.

In their study, Novak and Treagust (2017) inquired, "Do students integrate new evidence into their scientific explanations?" and employed a time-series research design to address this inquiry. Their findings indicated that while students initially faced no challenges in presenting evidence to substantiate their claims, they encountered difficulties in revising their claims when presented with new and conflicting evidence.

2.3.3 Challenges with Argument-Driven Inquiry

Sampson and Walker (2012) explored the obstacles faced by undergraduate students in learning science through ADI. The initial challenge involved providing sufficient background information, encompassing the laws and theories relevant to the investigated topic. Furthermore, students encountered difficulties in defining key terms and elucidating the significance of addressing the research question. The second challenge pertained to explaining the rationale behind data collection and experimental design, despite effectively detailing what they collected during the investigation. The third challenge involved elucidating the significance of the evidence and articulating why it supported the explanation. The fourth challenge related to the incorporation of tables in the reports; some students omitted data presentation, others used it incorrectly, and some utilized it appropriately but failed to make references. The final challenge was the inappropriate usage of science-specific terminology by the students.

Walker et al. (2019) investigated the challenges faced by undergraduate students in argumentation sessions within a laboratory course structured with ADI. The study findings revealed that students encountered difficulties in (1) modifying their claims, even when those claims were contradicted, and (2) providing justifications for their claims based on laws and theories. Additionally, colleagues observed that students tended to use evidence without proper warranting.

Kaçar and Balım (2021) explored the challenges faced by middle school students in learning science through ADI. The researchers highlighted that students encountered difficulties in expressing their ideas publicly, seeking the opinion of a purportedly knowledgeable friend to assess its reliability, being hesitant to change their ideas due to a fixed mindset or lack of knowledge about the subject, collaborating with group members, determining the research question and hypothesis, identifying variables, designing the experiment, managing and analyzing the data, formulating a claim based on the data, providing support for arguments, crafting counterarguments and rebuttals, assessing their peers' arguments, adjusting their own arguments based on peer evaluations, and comprehending the topic presented in the introduction, be it a scenario or concept cartoon.

CHAPTER 3

METHODOLOGY

In this chapter, the study's research methodology is explained. The chapter covers the revision of argument-driven inquiry, the pilot studies, research design, context, participants, data collection tools, data analysis, trustworthiness, and limitations of the study.

3.1 Revision of Argument-Driven Inquiry

Prior to the research, ADI method underwent revisions due to the identification of disparities between the theoretical framework and the practical implementation of the inquiry phase within the method (refer to Grooms et al., 2016; Walker et al., 2011). The following provides a breakdown for each stage of ADI, outlining whether the need for revision was evident and the reasons behind it.

Stage 1: Identification of the Task and the Research Question

In accordance with ADI theory (as proposed by Walker et al., 2011, Grooms et al., 2016), the teacher assumes the role of presenting the research question, introducing the subject matter, and guiding the investigative process. Similar to other methodologies, such as Learning Cycle, this stage naturally involves piquing students' curiosity, establishing connections between their past and current experiences, and providing clarity regarding the objectives of forthcoming activities.

In Stage 1 of the ADI application guidebook (authored by Grooms et al., 2016), which corresponds to the introductory section in the lab handout, students are presented with foundational knowledge. This theoretical knowledge serves as a basis for students to apply it during their investigations. However, it is important to note that this theoretical knowledge encompasses more information than their prior understanding, aiming to bridge the gap between their past knowledge and the present inquiry. Additionally, most of the lab handouts in the guidebook contain explanations that guide students in providing justifications for supporting their evidence. These justifications also serve as cues for the investigations that students are tasked with designing. In some lab handouts, you can find the claims that essentially serve as responses to the research questions (for example, Lab 8 and Lab 11). These practices, which entail presenting students with claims and justifications before they embark on investigations, run counter to the essence of inquiry-based learning. True inquiry fosters a curious mindset where students actively seek answers (as emphasized by Haury, 1993) and encourages students to indirectly acquire scientific knowledge by conducting their own scientific inquiries, rather than directly receiving scientific knowledge from instructors (as discussed by Jerrim et al., 2022, and Spronken-Smith, 2012). Consequently, in the first stage of the ADI method conducted in this study, theoretical information is intentionally removed and instead incorporated into the subsequent stages of the method. Moreover, the situation, which is going to be detailed in the following sections, has given rise to two distinct argumentation sessions, namely the empirical argumentation session and the theoretical argumentation session. Additionally, a research question has been formulated for each argumentation session, with a primary research question for the empirical argumentation session and a secondary research question for the theoretical argumentation session.

To capture students' interest effectively, the authors (Grooms et al., 2016) predominantly incorporate real-life examples in the introductory section. However, it is important to note that merely mentioning these examples does not inherently demonstrate how the acquired scientific knowledge can be applied in these or similar real-world scenarios. Consequently, the introductory section has been revamped to align with context-based learning principles, which involve learning within a context—specifically, the application of physics concepts in everyday life. Context-based learning, in its broadest sense, encompasses the social and cultural environment where students, teachers, and educational institutions are situated. It has the potential to facilitate knowledge transfer across different contexts and enhance learning by allowing students to revisit the same physics concepts within various real-life situations (as defined by Whitelegg & Parry, 1999). Consequently, each the ADI activity now commences with an intriguing contextual question, enabling students to arrive at answers by applying the knowledge they have acquired during the ADI activity.

Stage 2: Develop a Method and then Collect and Analyze Data

In accordance with ADI theory, the second stage centers on the generation and analysis of data. During this phase, students collaborate in groups of three or four individuals as they devise and put into action their own methods to address the research question.

Before embarking on the task of devising their own methods to address the research question in the ADI conducted in this study, students formulate an initial claim in response to the primary research question. This claim that is rooted in their prior experiences of the students serves as a hypothesis as the inquiry process entails the creation, testing, and refinement of hypotheses (as noted by Dewey, 1910, as cited in Barrow, 2006).

Stage 3: Develop a Tentative Argument

As per ADI theory, students formulate a preliminary argument in response to the research question. This argument typically comprises a claim (conclusion, explanation, or descriptive statement), evidence (measurements or observations), and a justification (explanation for why the evidence supports the claim).

Within the ADI conducted in this study, students modify their previously stated claims by taking into account the measurements or observations they have made in the previous stage. They then construct a comprehensive version of the argument, including the claim (conclusion, explanation, or descriptive statement), the empirical evidence from their own research, and the empirical justification derived from their research in response to the primary research question.

Stage 4: Argumentation Session

As outlined in ADI theory, students present their arguments to their peers and engage in critiquing each other's arguments. Following this session, all groups are given the chance to refine their arguments. This stage serves as a valuable opportunity for students to acquire the skills of sharing and critiquing.

Within the ADI conducted in this study, the argumentation session is segmented into two parts: the empirical argumentation session and the theoretical argumentation session. Between these two sessions, the theoretical knowledge that was removed from Stage 1 has been introduced. The empirical argumentation session involves the presentation of empirical evidence and empirical justifications derived from students' investigations. On the other hand, the theoretical argumentation session encompasses theoretical evidence and theoretical justifications, which are based on theoretical knowledge.

Stage 5: Explicit and Reflective Discussion

According to ADI theory, this is a whole-class discussion led by the teacher. Students share what and how they know and have the opportunity to discuss crosscutting concepts, the nature of science, and scientific inquiry.

In the ADI conducted in this study, the knowledge possessed by students and their understanding of it are documented in the information they write on the ADI activity sheet. Additionally, concepts related to the nature of science and scientific inquiry are indirectly conveyed. To prevent redundancy, this stage has been eliminated.

Stage 6: Write an Investigation Report

As per ADI theory, students individually compose investigation reports, which include components such as the objective, the methodology, and the argument. This process serves as a catalyst for promoting metacognitive thinking.

As a group activity, the ADI students of the study complete the activity sheet provided at the start of the activity while the activity is in progress.

Stage 7: Double Blind Group Peer Review

In accordance with ADI theory, each group examines multiple reports to provide feedback. During this phase, students acquire the skills of assessment and evaluation.

The double-blind group peer review stage was eliminated from the ADI conducted in this study, as it was deemed that the feedback obtained during the argumentation sessions was satisfactory. In its place, the elaboration stage was introduced to enable students to apply their newfound knowledge in different contexts.

Stage 8: Revise and Submit Report to the Instructor

As per ADI theory, following revisions made in response to the double-blind group peer review, students present their reports to the teacher.

In the ADI conducted, after revising their activity sheets based on the argumentation sessions, students submit these sheets to the teacher.

3.1.1 Implementation Process of Argument-Driven Inquiry in This Study

In this study, a more comprehensive analysis was conducted using TAP. Nevertheless, the ADI conducted in this study was originally developed using the claim, evidence, and justification model (McNeill & Krajcik, 2007). Two primary reasons account for this choice. Firstly, the original ADI adheres to the claim, evidence, and justification model. Secondly, the terminology utilized in TAP might be unfamiliar to students, and it was believed that introducing TAP could potentially pose an external barrier for the students. The subsequent sections outline the stages of the ADI conducted in this study along with detailed explanations.

Stage 1: Attraction of the Attention

If deemed necessary, the teacher initiates the ADI activity by providing preliminary background information for the investigation. Subsequently, the teacher introduces a contextual question to engage students in the activity and poses the primary and secondary research questions. As the activity unfolds, students utilize the knowledge they acquire to ultimately address both the contextual and research questions. The first stage of every ADI activity carried out in this research is presented in Appendix A.

Stage 2: Exploration

To begin, students initially formulate a provisional claim rooted in their prior experiences as a potential answer to the primary research question, which they document in the designated claim section of the activity sheet after the activity sheets are distributed. This claim essentially functions as a hypothesis that guides the development and execution of their investigation methods. Various claims put forth by students may find support in the evidence they gather, while others may be contradicted. Students are granted the freedom to explore in their own unique ways; there is no requirement for everyone to pursue identical investigations, nor is there an obligation to arrive at identical conclusions.

Once the claims have been formulated, the teacher initiates a whole-class discussion by asking students about their strategies for designing an investigation to substantiate these claims. This discussion includes inquiries about the tools and methods they intend to employ, with the teacher providing explanations if the tools are unfamiliar to the students. Subsequently, the teacher organizes students into groups and furnishes each group with a copy of the activity sheet. Students are expected to use this sheet to document their progress and findings throughout the activity. The activity sheet comprises sections for recording the research questions, claim, evidence, justification, investigation procedures, and the ultimate answer to the research questions. It is also crucial at this juncture for the teacher to elucidate specific safety measures and precautions.

Students then formulate a valid investigation to gather evidence to substantiate their claims. Later, students commence their investigations in collaborative groups, typically consisting of 2-4 students. Throughout this investigative phase, the teacher circulates among the groups, offering guidance and assistance as needed. All data collected and interpretations made by students are to be recorded in the evidence section of the activity sheet.

Stage 3: Emprical Argumentation Session

In this phase, students fill in the provided blanks on the activity sheet with their empirical evidence, either in support of or against their initial claims, as well as their investigation procedures. In this study, the empirical justifications derived from the students' investigations were not separately documented on the activity sheet. This was because the information within the investigation procedure already encompassed the students' empirical justifications. Once students have completed these sections on the activity sheet, they share their arguments and investigation procedures with the class and offer critiques of the claims, empirical evidence, and investigation procedures of other groups. The teacher's duties involve probing students' claims, evidence, and investigation procedures to unveil the empirical justifications held by the students, while also facilitating a thorough class discussion.

If claims, empirical evidence, and empirical justifications are inadequate, it becomes essential to pose one or more of the following questions to enhance the argumentation session.

- How can you refute your friend's claim if you have evidence that your claim is valid?
- What information would prove that your friend's claim is invalid?

- Is there anyone in the class who can prove that our friend's claim is invalid?
- Before deciding on this claim, were there other claims that you discussed in your group? Why did you give up other claims?
- How sure are you that your claim is valid? What can you do to be sure?
- How did you gather the data? Why did you use this method? Why did you collect the data?
- What did you do to ensure that the data you collected was reliable? What did you do to reduce the margin of error?
- How did you analyze the data? Why did you choose to do it this way?
- Could you have interpreted your measurements differently? Are you confident that you interpreted your measurements correctly?
- Why did you choose to present your evidence in this way?

If needed, students are provided with the chance to review and discuss each other's evidence and clarify their investigation procedures.

Stage 4: Explanation

During this stage, the teacher elucidates the theoretical principles underlying the investigation to the students. The theoretical evidence and theoretical justification are embedded within the theoretical knowledge.

Stage 5: Theoretical Argumentation Session

The teacher prompts students to explain why their empirical evidence supports or refutes their claims, utilizing the theoretical knowledge provided in the previous stage. Students share their responses and evaluate the responses of other groups. These student responses encompass both theoretical evidence and theoretical justification. The teacher guides the entire class in an argumentative discussion, similar to the empirical argumentation session. Subsequently, the teacher instructs students to record their responses in the "justification: the claim is supported/refuted because..." section of the activity sheet. The teacher then requests students to answer the primary and secondary research questions using the information they have acquired and record the answers in the conclusion section of the activity sheet. Lastly, the teacher revisits the contextual question posed at the activity's outset. When all the sections of the activity sheet are completed, students submit their activity sheets to the teacher.

As observed, the ADI activity sheet does not include distinct sections for empirical justification or theoretical evidence. Instead, it features an evidence section designated for empirical evidence and a justification section intended for theoretical justification. Introducing separate sections for empirical evidence, empirical justification, theoretical evidence, and theoretical justification could lead to confusion and become an extraneous challenge for students, potentially resulting in redundant information. The primary objective was not to instruct students in the theoretical intricacies of the method but rather to seamlessly employ the method as a vehicle for imparting scientific knowledge and scientific skills while avoiding repetition of content.

Stage 6: Elaboration

Students are provided with the chance to put into practice and expand upon the theoretical knowledge they have acquired.

An example of the ADI activity materials is provided in Appendix B.

3.2 Development of Argument-Driven Inquiry Activities

This research comprises three pilot studies, all with a shared goal of crafting and improving the Argument-Driven Inquiry (ADI) activities implemented in this study. The researcher created these activities based on the initial five objectives outlined in the 10^{th} grade optics unit of the Turkish physics curriculum. The objectives were illumination, shadows, law of reflection, image formation at a plane mirror, and field of view at a plane mirror.

The "MSE 407 Laboratory Applications of Secondary Science Education II" course, which is an elective course offered by the Mathematics and Science Education Department at Middle East Technical University, was redesigned by the researcher during the spring semester of the 2017-2018 academic year. The primary goal of this redesign was to convert the course into a platform where Pre-Service Physics Teachers (PPTs) could both learn about inquiry, argumentation and the ADI conducted and gain practical experience in learning and teaching with the ADI. This course was conducted for four hours per week. The initial pilot study, which took place within the MSE 407 course, extended over a 10 weeks. Six students were enrolled in the course, and all of them participated in the study. Among these participants, there were five senior students and one student enrolled in the Master of Science program within the same department, totaling six participants. Five senior students, referred to as PPTs, took turns instructing their peers in physics using the ADI materials created by the researcher. Additionally, the other participant, who was also a physics teacher, delivered a physics lesson through the ADI to his own students.

The participant who assumed the role of a teacher during the first week of the MSE 407 course received comprehensive instructions regarding the implementation of the first ADI activity to be executed before the lesson. The ADI implementation took place during the initial week. During the ADI implementations, the participants who took on the role of students worked in groups of 2 or 3 individuals. The implementations were followed by interviews in the subsequent week. Individual interviews were conducted with the participants engaged in teaching physics with the ADI, while a group interview was held with the participants learning physics through the ADI. The ADI implementation and the interviews were recorded on video. The video recordings, student-filled activity sheets from the initial activity, and the researcher's observation notes played a role in recognizing the challenges faced in the process of learning and teaching physics through the ADI. This led to adjustments in the ADI materials planned for use in the upcoming week. The pilot study unfolded over a 10-week period, characterized by a cycle of teacher training, the ADI implementation, interviews, data analyses, and revisions. Revisions involved fine-tuning research questions, contexts, design sketches for investigations, and a decrease in the number of conceptual questions.

The second and third pilot studies were carried out during the spring semester of 2018-2019, spanning a period of 5 weeks for each of them. These pilot studies involved a total of 7 classes of 10th grade students from two different high schools in Ankara, including all students from these classes, their physics teachers, the researcher of the study, and two assistants of the researcher. Two PPTs from the previous pilot study were selected to serve as the researcher's assistants. It is also worth noting that 10th grade students are of average academic level compared to the broader Turkish student population.

Before the implementation of the ADI activities, all teachers received a 3-hour training session on how to teach physics through the ADI activities they would be employing. During the ADI implementations, 10th grade students collaborated in groups of four, and each ADI implication was closely observed by the researcher or the assistants and the observation notes were taken. Following each ADI implementation, convenient teachers and students were chosen for interviews. The interviews were recorded in audio format. Teacher interviews were conducted individually, while student interviews took place in groups of four. Interviews were conducted with all the teachers and a majority of the students by the researcher or the assistants during the implementation. By analyzing the activity sheets completed by the students, the interviews, and reviewing the observation notes, any difficulties encountered in the process of learning and teaching physics using ADI were pinpointed. Subsequently, the ADI materials scheduled for implementation in the following week were revised based on the feedback gained. In these pilot studies, the cycles of the ADI application, interviews, data analysis and, revisions continued for a duration of 10 weeks. In the second pilot study, changes included adjustments to research questions, timing specifications, illustrations of investigation designs, and the integration of videos in situations with insufficient visuals, along with clarifications in both verbal and visual forms. In the third pilot study, refinements were implemented to improve verbal and visual clarifications.

3.3 Research Design: Instrumental Case Study

The most suitable qualitative research design for this study is the case study design. Case study design involves an in-depth exploration of an issue by examining one or more cases within a bounded system, such as a particular setting or context (Creswell, 2007). In a case study, researchers gather comprehensive and detailed data from various sources, including interviews, video recordings, and documents (Creswell, 2007).

Different types of qualitative case studies are categorized according to the researcher's intended use. Stake (1995) identifies three primary types: intrinsic case study, instrumental case study, and collective case study (also known as multiple case study).

In an intrinsic case study, the researcher's primary focus is on the case itself, typically because the case represents a unique or exceptional situation, such as a specific program or an exceptionally gifted student. Unlike intrinsic case studies, instrumental case studies shift the researcher's focus away from the case and instead concentrate on a particular issue or concern, such as challenges in implementing a student-centered learning method in a classroom context. In this type of study, the researcher selects the case that best illustrates the issue or concern, making it observable and illustrative. On the other hand, in a collective case study, the researcher directs attention to an issue or concern that spans multiple cases. For instance, the researcher might investigate issues related to implementing a student-centered learning method in two different classes—one consisting of low-achieving students and the other with high-achieving students. This design allows for comparisons and contrasts to be drawn between these cases.

This research study aligns seamlessly with the instrumental case study design. The central focus of inquiry revolves around the challenges encountered by PPTs in their learning and application of the ADI. The implementation of the ADI activities, which was specifically crafted by the researcher, serves as the chosen case to address this issue.

3.4 Context

The "MSE 407 Laboratory Applications of Secondary Science Education II" course, which is an elective course within Mathematics and Science Education Department at Middle East Technical University, underwent a redesign led by the researcher during the fall semester of the 2020-2021 academic year. This redesign aimed to transform the course into a platform where PPTs could both learn about the ADI and gain practical experience in learning and teaching via the ADI method. This course ran for four hours per week and served as the context for this study.

The course comprised three distinct phases: the learning phase, the preparation phase, and the teaching phase. In the learning phase, PPTs acquired knowledge about inquiry, argumentation, and ADI, and subsequently participated in five ADI activities as students. The students were organized into random pairs for each ADI activity, with each group completing an activity sheet during the activities. There are two primary motivations behind this approach. Firstly, it aims to remove any potential external barriers that might emerge due to conflicts within groups in subsequent activities. Secondly, during the argumentation sessions, the goal is to encourage students to engage in discussions within a harmonious atmosphere rather than a competitive one. This is because when the groups are mixed for each activity, the students have the opportunity to become better acquainted with one another and foster friendships. The teaching assistant, who was also the researcher, closely monitored and guided the students' performance. After each ADI activity, the students received the materials of the activity which are the teacher guide, presentation, and student handout. The primary aim of this phase was to familiarize the students, who were PPTs, with the ADI physics activities and help them develop various scientific skills, particularly argumentation and scientific process skills, to use in their future careers.

In the preparation phase, each PPT created an ADI activity on a topic of their choice from the Turkish high school physics curriculum. Initially, the PPTs submitted their first drafts of the activities to the teaching assistant, who then provided feedback. Subsequently, the PPTs revised their activities based on the feedback and submitted their final versions.

Moving to the teaching phase, the PPTs took on the role of instructors and conducted their activities as teachers on three occasions. In the first instance, they engaged in peer teaching, delivering lectures to their fellow PPTs using their own activities. During this session, the teaching assistant observed but did not intervene. Field notes were taken, and feedback was provided once the session concluded. In the second and third instances, the PPTs carried out student teaching, instructing two different high school classes using their revised activities. To create the high school classes, online applications were collected from high school students from various regions of Türkiye, and a random selection was made from among the applicants. When forming the classes, a key consideration was ensuring that the grade level of the ADI activity matched the grade level of the high school students. In other words, if the activity was designed for a specific topic from the 9th grade physics curriculum, the students chosen for that activity were selected from the pool of 9th grade students. Another key consideration was the number of the students in the classes. During the first student-teaching session, there were 15 students in each class, but this number increased to 20 during the second student teaching. The decision to limit the number of students in the initial student teaching session was intentional, as it was believed that having a larger group of students might introduce external barriers. The learning experiences from the learning phase, emphasizing inquiry and argumentation, contributed to the PPTs' confidence in implementing the ADI as physics teachers during this phase. The second and third teaching sessions did not involve monitoring, guidance, or feedback from the teaching assistant.

Due to the COVID-19 pandemic, the course was conducted in an online format using Zoom. To facilitate the learning process, the teaching assistant shipped the required experimental materials to the PPTs via a courier service.

3.5 Participants

This study employed purposive sampling (Patton, 1990) to gain a more profound understanding of the challenges encountered by PPTs when learning and teaching via the ADI. The study focused on three out of ten students enrolled in the MSE 407 course during the fall semester of the 2020-2021 academic year, specifically those who were among the four lowest achievers. One of the lowest-achieving students was considered a unique case due to special circumstances and was not included in the primary analysis. The rationale for selecting the lowest-achieving students was their greater difficulty in learning and teaching via the ADI compared to their peers. The selection of these three lowest-achieving students, referred to as PPTs, was based on several criteria, including their performance in activity sheets, midterm results reflecting improvement in optics content knowledge, argumentation skills, and scientific process skills, as well as their performance in the learning and preparation phases.

All students enrolled in the MSE 407 course voluntarily participated in this study, and consent was obtained from each student. Below, brief descriptions of the teaching assistants and the three PPTs, including their gender, age, and academic backgrounds were provided.

3.5.1 Teaching Assistants

Two teaching assistants were involved in this study. The primary teaching assistant for the MSE 407 course, who also served as the researcher for this study, was a 34-

year-old female. She earned her Master of Science degree in Physics Education from the Department of Mathematics and Science Education at Middle East Technical University in 2011. In the same year, she commenced her Ph.D. program in the same department, at the same university. Between 2012 and 2022, she served as a research and teaching assistant in the same department at the same university. Prior to this research, she had several years of experience as a teaching assistant in courses related to high school physics curriculum review, methods of science teaching in secondary education, laboratory applications in secondary science education, school experience, and practice teaching. At the time of this study, she was also pursuing her Ph.D. in the same department. Her responsibilities in the MSE 407 course included instructing the ADI and teaching physics through the ADI activities, as well as facilitating the PPTs in teaching physics through the ADI activities.

The second teaching assistant for the MSE 407 course was a 28-year-old female. She was one of the participants in the first pilot study. In 2018, she earned her bachelor's degree in Physics Education from the Department of Mathematics and Science Education at Middle East Technical University. The following year, she began her Master's program in the same department at the same university. Since 2020, she has been working as a research and teaching assistant in the same department. Prior to this research, she had one year of experience as a teaching assistant in various courses, including high school physics curriculum review, methods of science teaching in secondary education, laboratory applications in secondary science education, and practice teaching. During this study, she was also pursuing her Master's degree in the same department. Her responsibilities in the MSE 407 course included monitoring students' progress in all phases and taking field notes.

3.5.2 Students

To protect the confidentiality of the participants, pseudonyms were employed in this chapter and subsequent ones.

Ece, a 23-year-old junior female student, was pursuing a major in Physics Education within the Department of Mathematics and Science Education. She had completed approximately half of the physics courses provided by the Department of Physics. During the same semester as the MSE 407 course, she was also taking courses in curriculum development and instruction, as well as high school physics curriculum review I. Notably, she was not currently enrolled in methods of science teaching in secondary education I, methods of science teaching in secondary education II, high school physics curriculum review II, laboratory applications in secondary science education I, school experience, or practice teaching at the time of this study.

Banu, a 23-year-old junior female student, was pursuing a degree in Physics Education within the Department of Mathematics and Science Education. She had successfully completed approximately half of the physics courses offered by the Department of Physics. In the same semester as the MSE 407 course, she had enrolled in methods of science teaching in secondary education I and laboratory applications in secondary science education I. Prior to the commencement of this study, she had completed courses in high school physics curriculum review I and curriculum development and instruction. Notably, at the time when this study was conducted, she was not currently enrolled in methods of science teaching in secondary education II, high school physics curriculum review II, school experience, or practice teaching.

Begüm, a 23-year-old sophomore female student, was pursuing a degree in Physics Education within the Department of Mathematics and Science Education. She had successfully completed approximately half of the physics courses offered by the Department of Physics. Additionally, she had taken high school physics curriculum review I and curriculum development and instruction during the same semester as the MSE 407 course. Notably, at the time when this study was conducted, she had not yet enrolled in courses in methods of science teaching in secondary education I, methods of science teaching in secondary education II, high school physics curriculum review II, laboratory applications in secondary science education I, school experience, or practice teaching.

3.6 Data Collection Tools

This study employed multiple data collection tools to pinpoint the challenges encountered by PPTs when learning and teaching via the ADI, as well as to understand the variation in the challenges encountered by each PPT based on their experiences. The data collection tools encompassed various sources, including video recordings (covering the learning phase, teaching phase, semi-structured interviews, and writing feedback sessions), course materials (comprising teacher guides, presentations, student handouts, and activity sheets), and reflection papers.

3.6.1 Video Recordings

There is a combined total of 48 video recordings, with 5 dedicated to the learning phase, 9 for the teaching phase (3 per PPT), 3 for feedback sessions, and 31 for the semi-structured interviews. These videos were all recorded via Zoom.

The ADI activities during the learning phase were recorded from start to finish, with each activity having an average duration of about 2 hours. This resulted in approximately 10 hours of video recordings for the learning phase, which were meticulously reviewed, transcribed, and analyzed. Within these video recordings, the researcher closely observed the classroom dynamics, group interactions, and the responses of each group. Throughout the learning phase, the primary teaching assistant maintained control over the video recordings.

Most of the ADI activities were conducted in the main room where the teaching assistants and all the PPTs were present. However, during the exploration stage and activity sheet completion, the PPTs worked in separate groups, each assigned to a dedicated breakout room. This arrangement aimed to prevent inadvertent exposure to other groups' work and discussions, mitigating the potential for confusion.

Moreover, this separation was designed to ensure that students did not learn from other groups' investigative mistakes at this stage. Such errors were intended to be discussed and critiqued during the argumentation sessions to foster critical thinking skills.

As the primary teaching assistant managed the video recording, the areas where the primary teaching assistant was present were captured on video. Since most of the ADI activities occurred in the main room, all aspects of these activities held there were recorded. When the PPTs were divided into different breakout rooms, the primary teaching assistant moved between rooms to provide guidance, and the activities in those rooms were also recorded. Areas not under the direct supervision of the primary teaching assistant were not recorded. Nevertheless, discussions from all rooms were thoroughly examined during the empirical argumentation session and documented on the activity sheets. Therefore, the omission of certain rooms from video recording did not pose a limitation to this study.

The ADI activities conducted during the teaching phase were meticulously recorded, capturing the entirety of each activity, with an average duration of approximately 2 hours per session. In this context, nearly 18 hours of video recordings for the teaching phase were carefully reviewed, and if necessary, re-examined, transcribed, and subsequently analyzed. Within these video recordings, the researcher closely observed the classroom dynamics, group interactions, and the responses of the participating groups.

It is noteworthy that the control of video recordings during this phase rested with the PPTs, who were also the creators and instructors of the lessons during the teaching phase. Much like the learning phase, the majority of the ADI activities during the teaching phase took place in the main room. During the exploration stage and while students completed the activity sheets, the students, who were the PPTs' own students, worked in separate groups, each group occupying a distinct breakout room. As the PPTs had control over video recording, only the rooms where the PPTs were physically present were recorded. Consequently, every aspect of the ADI activities held in the main room was captured on video. In cases where the PPTs' students were allocated to different breakout rooms, those rooms where the PPTs were not physically present were not recorded. Nevertheless, it is important to note that discussions from all rooms were thoroughly addressed during the empirical argumentation session and documented on the activity sheets. Thus, the absence of the video footage from the certain rooms did not pose a limitation to this study.

For each PPT, the video recording of the interview process encompassed several distinct components. These included:

1. A pre-learning interview conducted just before the commencement of the learning phase.
2. A post-learning interview conducted immediately after the learning phase.
3. Pop-interviews following the learning phase activities. However, it is important to note that pop interviews were not deemed necessary after the fourth and fifth activities for Ece, as she had successfully addressed the challenges she initially encountered.
4. A post-writing interview conducted immediately after the PPTs submitted their revised ADI activities.
5. A post-teaching interview carried out after each teaching session in which the PPTs instructed their own activities during the teaching phase.

All these interviews were recorded in their entirety. The pre-learning interviews typically lasted an average of half an hour, while the post-interviews spanned between 1 to 1.5 hours each. The duration of video recordings for pop interviews varied from one PPT to another. For instance, while the one pop interview for one PPT lasted about 10 minutes each, another PPT's pop interview was approximately 1 hour in duration.

In total, the extensive process of reviewing, transcribing, and analyzing these interviews encompassed almost 28 hours of video recordings. It is noteworthy that each interview was conducted between the primary teaching assistant and a single PPT. During the development of interview questions, valuable insights from observations during the learning, teaching, and preparation phases, field notes, and expert opinion from the co-supervisor were consistently considered and incorporated. Interview questions can be found in Appendix C.

A writing feedback session took place immediately after the PPTs submitted their initial drafts of the ADI activities as part of the preparation phase. The duration of video recordings for these feedback sessions varied among the PPTs. For example, two of the PPTs' feedback sessions lasted approximately 20 minutes each, while one PPT's feedback session extended to around 2 hours.

In total, the comprehensive process of reviewing, transcribing, and analyzing these feedback sessions involved nearly 2.5 hours of video recordings. It is important to note that each feedback session was conducted individually between the primary teaching assistant and a specific PPT.

3.6.2 Materials of the Argument-Driven Inquiry

An ADI activity comprises several components, including a teacher guide that provides a detailed, step-by-step explanation of how to conduct the ADI activity, a presentation designed for both the teacher and students to use as a guide during the activity, a handout given to students at the end of the activity that contains essential information covered during the activity, and an activity sheet designed for students to utilize the sample investigation box on the initial page and complete the second page while conducting the activity (refer to Appendix B for details).

During the course of this study, the following materials and documents were utilized as data collection tools:

1. Five activity sheets filled out by each PPT during the learning phase.
2. One draft version and one revised version of the ADI materials generated by each PPT during the preparation phase.
3. 44 activity sheets completed by the PPT's students (9 from peer teaching, 15 from first high school teaching, 20 from second high school teaching) during the teaching phase.

3.6.3 Reflection Papers

Following each activity in the learning phase, every PPT composed a reflection paper in response to 11 questions designed to help them recognize the difficulties encountered during this phase. Consequently, data collection also encompassed 15 reflection papers. The guideline for the reflection paper can be found in Appendix D.

3.6.4 Observations and Field Notes

The teaching assistants monitored the learning phase and the peer teaching sessions. During their observations, both teaching assistants took detailed field notes. Additionally, during the post-peer teaching interviews, all students enrolled in the MSE 407 course were questioned about whether they noticed any challenges faced by their peers while teaching physics using the ADI activities they had created. The observations and field notes played a vital role in data collection and analysis, assisting in participant selection and providing valuable insights during post-interviews.

3.7 Data Analysis

The method employed for data analysis in this study was the constant comparative method, which was originally introduced by Glaser and Strauss (1967) for the purpose of developing grounded theory. In this method, researchers begin by examining specific incidents derived from interviews, field notes, or documents and then compare them to other incidents within the same or different data sets (Merriam

& Tisdell, 2016). These initial comparisons lead to the formation of provisional categories, which are further compared among themselves and with additional instances until a theory emerges (Merriam & Tisdell, 2016). Due to its inductive and comparative nature, the constant comparative method is widely utilized in qualitative research by numerous researchers for generating findings, even without the intention of constructing a grounded theory (Charmaz, 2014; Merriam & Tisdell, 2016).

In a sequential manner, the data sets for a PPT were examined, encoded, and re-encoded until arriving at the final set of codes. Initially, the recording of the pre-learning interview was reviewed and transcribed. The challenges encountered in learning physics prior to the MSE 407 course were identified and encoded. Next, the video recording of the first learning phase activity was observed and transcribed. The challenges faced during this activity were categorized and encoded. Subsequently, the activity sheet and the reflection paper for this activity were scrutinized, and the challenges found within them were categorized and coded. Later on, the pop-interview video recording for the same activity was viewed and transcribed, and the challenges identified therein were categorized and encoded. The codes generated from the data of the first activity were then compared and contrasted with those derived from the pre-learning interview data. If any newly established codes conflicted with those from the previous dataset, the prior dataset was re-evaluated and re-coded. This process was repeated for subsequent activities in the learning phase involving the same PPT. Following this, the data sets from other phases underwent a similar analysis. Once the codes for the first PPT were established, the same procedure was applied to analyze the second and third PPTs. Through this methodical process, specific codes were developed.

The data analysis followed a cyclical and iterative approach, involving a minimum of three rounds of review across all data sets to reach the final results. After the initial analysis of all participants, a preliminary framework for analyzing the challenges was established. The appropriateness of the initial framework was validated through a comprehensive literature review and discussions with colleagues knowledgeable in argumentation and inquiry processes.

The next round involved a comprehensive reanalysis of the complete data set. During this stage, there was an effort to conceptualize and structure the codes in alignment with the overarching analytical framework. This included identifying the relationships between codes, defining the scope of each code, and providing concise summaries of their contents. Specifically, the challenges faced by the PPTs within the general framework were identified, and grouped into categories and subcategories. Furthermore, the meanings associated with these categories and subcategories were elucidated based on the shared characteristics among the challenge codes experienced by the PPTs in each phase.

The final round involved a thorough validation of the categories. The entire data set was subjected to another round of analysis, focusing on the attributes of the challenges faced by the PPTs, as well as the interpretations of the categories and subcategories.

Upon examining the collected data, it became evident that the PPTs faced challenges in various skills, such as argumentation skills, science process skills, and the ability to notice and comprehend key concepts. The analysis revealed that challenges related to science process skills, noticing skills, and conceptual understanding are precursors to challenges in argumentation skills. Therefore, this study focuses on presenting findings related to challenges in argumentation skills. These challenges involve difficulties with the six elements of an argument (claim, data, warrant, backing, rebuttal, and qualifier) within the TAP framework. The study encompasses both empirical and theoretical argumentation sessions, with the terms "empirical" or "theoretical" added to specify the type of argumentation session where a challenge arises. For instance, if a challenge with a warrant occurs in an empirical argumentation session, it will be termed an empirical warrant. If the challenge occurs in a theoretical argumentation session, it will be referred to as a theoretical warrant.

The PPTs aim to support or refute the same claim, irrespective of whether the argumentation session is empirical or theoretical. Consequently, appending "empirical" or "theoretical" to the claim element holds no significance.

Here are Figures 3.1 and 3.2 to enhance clarity.

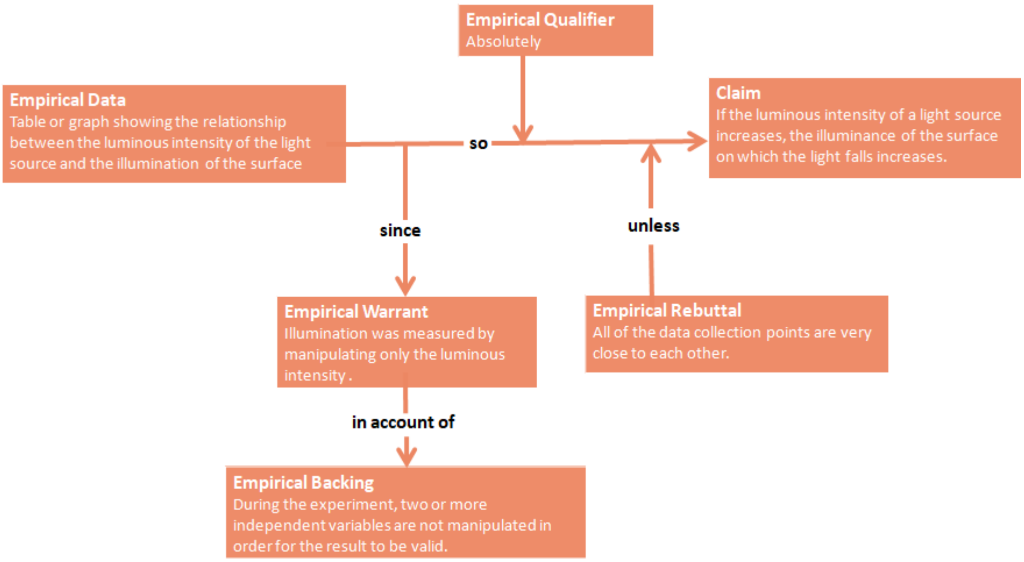


Figure 3.1. Following TAP, an instance from an empirical argumentation session

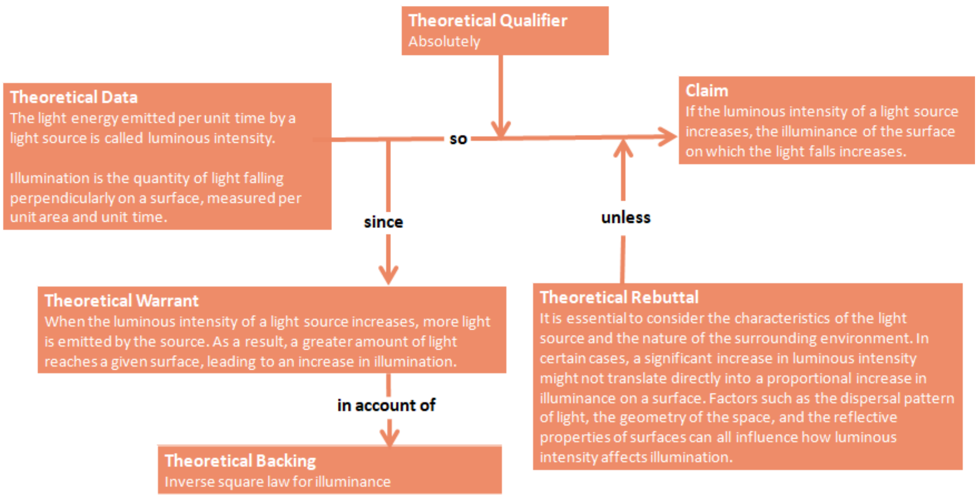


Figure 3.2. Following TAP, an instance from a theoretical argumentation session

It is important to acknowledge that challenges with any of the TAP elements may suggest that challenges are experienced with other TAP elements. For instance, if invalid data is presented by a student in an argumentative discussion, there is the likelihood that the warrant presented by s/he is also problematic. In this example, since the origin of the problem is the data, only data-related challenges were coded in this case. This approach was consistently followed throughout the study.

3.8 Trustworthiness

In qualitative research, trustworthiness involves assessing the precision and reliability of the findings, whether they stem from the researcher, the participant, or someone reading the study (Creswell & Miller, 2000). Differences in how reliability and validity are established in qualitative and quantitative research arise from the unique features of qualitative research design. Within qualitative research, Lincoln and Guba (1985) introduced the concepts of credibility, transferability, dependability, and confirmability to correspond to the roles of internal validity, external validity, reliability, and objectivity, respectively, in quantitative research. These criteria serve as measures of the study’s trustworthiness.

3.8.1 Credibility

Lincoln and Guba (1985) highlighted that credibility, which they equated with internal validity, holds the utmost significance in establishing the trustworthiness of a study. They put forward several strategies to bolster credibility, such as "prolonged engagement, persistent observation, triangulation (data sources, methods, investigators), peer debriefing, member checking, the reflexive journal" (p. 328). In this study, the majority of these strategies were implemented.

3.8.1.1 Prolonged Engagement

According to Lincoln and Guba (1985), prolonged engagement at the research site serves dual purposes. One of these aims is to achieve a comprehensive understanding of the research site, thus preventing any potential data distortion. As mentioned earlier, the researcher has possessed extensive expertise in the relevant field. This expertise has endowed the researcher with knowledge about the laboratory environment and the equipment used in experiments. It has also facilitated a deep understanding of the Turkish high school physics curriculum and the ability to develop physics lessons tailored to student-centered methods that align with the curriculum's objectives and limitations. Furthermore, it has guaranteed that the researcher possessed the qualifications to prepare physics teachers who were well-prepared for the Turkish educational system.

Another aim of prolonged engagement is to give researchers the chance to establish trust. In qualitative research, it is essential for a researcher to create an environment in which participants feel at ease and are encouraged to express themselves candidly (Bogdan & Biklen, 2007). Prior to this study, the researcher also held instructional roles in other courses attended by the participants. Consequently, she had the opportunity to establish a close familiarity with the participants during the study. Also, the MSE 407 course was designed with the intention of fostering a comfortable atmosphere for participants. There was no hierarchy between the teaching assistants and the participants. During the argumentation sessions, participants could openly discuss their own mistakes and those of their peers. The researcher who was the primary teaching assistant actively participated in both the learning phase and the peer teaching session of the teaching phase, within the MSE 407 course. Moreover, the researcher shared personal contact information, including phone number and email address, with the participants to facilitate communication outside of class. In summary, the researcher reassured the participants that she was readily available to assist them whenever they required support.

3.8.1.2 Persistent Observation

Lincoln and Guba (1985) described the role of persistent observation as concentrating on the study's intended goals and pinpointing the key aspects of the situation that align with those objectives. The participants were continuously observed in classroom settings and recorded on video during the entire learning phase, the teaching phase, the feedback, and the interview sessions. These video recordings were thoroughly analyzed to achieve a comprehensive grasp of the challenges encountered by the participants. This iterative process was repeated at least two additional times until specific codes, categories, and detailed descriptions were established.

3.8.1.3 Triangulation

Triangulation stands out as a widely employed technique for enhancing the credibility of qualitative research. Its effectiveness lies in the utilization of multiple approaches to counterbalance the limitations that may arise when relying solely on a single investigator or method (Denzin, 1978).

There are four distinct types of triangulation: collecting data methodologies, data sources, multiple investigators, and theory (Lincoln & Guba, 1985). Data collection involved a methodological triangulation, combining various data sources, such as video recordings of the ADI activities, individual interview videos, the ADI materials, and reflection papers. It is important to note that triangulation of data is not achievable when multiple sources provide divergent perspectives or ideas (Yin, 2003). The research gathered data from diverse sources, establishing data source triangulation. In essence, the accuracy of the findings was corroborated by examining them from different perspectives, including those of the teaching assistants and the MSE 407 course students. Investigator triangulation was also implemented since two researchers who were the teaching assistants were involved throughout the entire process. These researchers observed the classroom and documented field notes regarding the study’s participants, contributing valuable insights and ideas concerning the challenges faced by the PPTs across all the ADI phases. Lastly, for the purpose of theory triangulation, an exploration of the theoretical foundations related to the difficulties encountered by students during their learning via inquiry, argumentation, and ADI, as well as the challenges faced by PPTs and teachers when employing these same instructional methods, was undertaken. By comparing and verifying the consistency of information gathered from various methodologies, a more precise understanding of the challenges experienced by the participants was attained.

3.8.1.4 Peer Debriefing

Peer debriefing involves seeking input and consultation from one or more colleagues who hold no personal interest in the study, with the aim of bolstering the research's validity. Its purpose is to delve into aspects of the inquiry that may otherwise stay hidden within the researcher's own thoughts (Lincoln & Guba, 1985). In the study, the researcher independently analyzed all the data and then conveyed and elucidated the findings to a colleague. The researchers had a difference of opinion in just one instance. The second researcher contended that there were challenges related to an invalid experiment design for a group of students who claimed they created an umbra without considering daylight in the shadow activity. However, the researcher in this study maintained that when daylight was controlled for, the students' experiment was valid. The difficulty encountered by the students was seen as a challenge related to controlling variables, and this argument persuaded the second researcher. They engaged in comprehensive discussions concerning all findings and interpretations of the experiences until they reached a mutual consensus. Additionally, the researcher sought input and exchanged thoughts with other colleagues who possessed a general understanding of the study. Peer debriefing helped reduce bias and provided clarity in the interpretations regarding the participants' challenges.

3.8.2 Transferability

Transferability corresponds to the concept of external validity and the extent to which research findings can be applied to other similar situations with comparable research questions (Guba, 1981). In qualitative research, the results may not necessarily apply to analogous situations, and generalizability is often not pursued as a primary objective, as some qualitative researchers argue (e.g., Denzin, 1983). According to Lincoln and Guba (1985), a qualitative researcher cannot definitively establish the external validity of a study; her/his role is to offer a thick description that allows interested researchers to decide whether applying the findings to their own context is a feasible option. In this study, the researcher provided comprehensive information about the ADI, the context, the process, and the participants to facilitate the transferability of the findings, but not generalizability.

3.8.3 Dependability

Dependability, which pertains to the reliability of research findings in terms of their replicability and consistency (Lincoln & Guba, 1985), was ensured through a rigorous process. To enhance reliability, the ADI activities were reviewed by 20 different experts. Each ADI activity was independently assessed by four experts, with two of them being physics teachers and the other two being experts in pure science or science education. All activities were subsequently revised based on the feedback provided by these 20 experts. The objective of this review was to ensure that the activities aligned with both the theoretical framework and the curriculum objectives.

Furthermore, three separate pilot studies were conducted to evaluate the level and effectiveness of the ADI activities used in the learning phase. The first pilot study involved PPTs in the MSE 407 course at Middle East Technical University. The second and third pilot studies were carried out with 10th grade physics students in seven different classes across two distinct high schools. It is worth noting that, without the pilot studies carried out in high schools, the alignment of the ADI activities with the 10th grade Turkish physics curriculum would not have matched the proficiency level of 10th grade Turkish students. This is because the proficiency level of Turkish high school students tends to lag behind the expected learning outcomes outlined in the curriculum. These high school pilot studies offered compelling evidence of the disparity between theory and practical classroom realities. Additionally, all the data collection instruments were developed in consultation with the co-supervisor.

Ultimately, segments of data from each phase were randomly chosen and subjected to coding by an inter-rater coder, who happened to be a research assistant at the same university. Before commencing the inter-rater coding, the codes were explained, and she received detailed instructions on how to carry out the coding and establish connections within the data. This measure was taken to ensure that the researchers shared a mutual comprehension, including setting benchmarks for the coding process. Subsequent to completing the coding, the inter-rater coder and the researcher convened to compare their respective sets of codes. The coding and linking procedures closely mirrored each other. Any discrepancies in the links and codes were thoroughly discussed until conflicts were resolved, leading to a consensus.

3.8.4 Confirmability

Confirmability refers to the practice of reducing researcher bias by substantiating study findings with reference to raw data and providing logical explanations, as outlined by Yıldırım and Şimşek (2006). An important method for ensuring confirmability is the utilization of an audit strategy. In this context, both the co-supervisor and a research assistant specializing in physics education thoroughly assessed the data collection and analysis procedures, along with their alignment and consistency.

3.9 Ethical Issues

Ethical approvals were secured from the Ethical Committee at METU and the Ministry of National Education for both the main and pilot studies (Refer to Appendix E).

The data were gathered during the physics lectures in the high schools for the second and third pilot studies. Prior to commencing the pilot study, the students received comprehensive information about the research, the data collection procedures, and the type of data to be collected. They participated in the study voluntarily and were informed of their option to withdraw from the study at any point during the process.

Furthermore, strict confidentiality measures were adhered to, with none of the students' names being used at any point. All data sets remained confidential, and only the researcher had access to the data. It is also important to note that the data collection tools were not utilized for grading the students.

In both the main study and the initial pilot study, data collection took place within an elective course (MSE 407). Consequently, during the initial course meetings, students were thoroughly briefed about the research, the data collection procedures, and the nature of the data to be gathered. This comprehensive information covered various aspects, ranging from the course details to the use of video cameras, interviews, and the submission of reflection papers.

Following this detailed explanation, all ten enrolled students opted to participate in the study voluntarily. They were explicitly informed of their right to withdraw from the study at any point during its duration. Consent forms, providing a comprehensive overview of the entire process (Refer to Appendix F), were obtained after the initial weeks of the courses.

Furthermore, strict confidentiality measures were in place to protect the privacy of the PPTs. Their names were never disclosed, and pseudonyms were employed for data analysis and reporting. The researcher exclusively shared the data with experts to gather feedback and conduct data analysis. It is also important to note that the data collection tools were not utilized for the purpose of grading the PPTs.

No participants were subjected to deception or harm in this study. Moreover, the researcher refrained from passing judgment on the PPTs, high school teachers, or high school students throughout the study, fostering a sense of safety among the participants. Similarly, in both the main study and pilot studies, all participants became acquainted with the researcher, ensuring that the researcher's presence in the classroom settings had no adverse effects on the participation of teachers, students, or PPTs. Additionally, in the main study, the PPTs became accustomed to the presence of video recordings throughout the entire process, eliminating any ethical concerns associated with video recording.

Furthermore, the researcher did not overlook any ethical issues that might arise during the data analysis. In this study, the data for the 3 selected lowest-achiever PPTs were uniformly analyzed, with no data left unexamined. Likewise, there were no instances of data corruption during the analysis process. The researchers adhered to the codes and their respective meanings throughout the analysis.

3.10 Limitation

The current study has three limitations: (1) Content of the activities were limited to the 10th grade Turkish physics curriculum, (2) activities were limited to 2 class hours, and (3) the findings were limited to the implications of the ADI in online settings.

CHAPTER 4

FINDINGS

This chapter delves into the examination and interpretation of the data in relation to the research questions. The primary aim of this study was to pinpoint the challenges encountered by PPTs during the learning, teaching, and creation of ADI teaching materials within ADI (Argument-Driven Inquiry) activities.

To start with, the challenges faced by the PPTs in various roles: as learners in ADI activities, as integrators of ADI into the Turkish physics curriculum, and as instructors in implementing ADI activities were detailed and categorized. Moving on, the challenges faced by each PPT in accordance with their experience were determined.

The researcher acquired data from an ADI course she had designed. The primary data sources used in the analysis included video recordings of the ADI activities, one-on-one interviews, materials related to ADI, reflection papers, and field notes. The collected data underwent analysis using the constant comparative method, as previously described in the Methodology Chapter. The results of this analysis are presented in the subsequent sections.

4.1 Challenges of PPTs

This section encompasses challenges faced by PPTs in various phases of the MSE 407 course, including their roles as the ADI learners, responsibilities in incorporating the ADI into the Turkish physics curriculum, and roles as instructors implementing the ADI activities. The analysis of data and results is divided into three distinct sections, each of which will be elaborated upon individually with detailed explanations.

The study, outlined in the Methodology chapter, revealed challenges among the PPTs in argumentation skills, particularly focusing on the six elements of an argument (claim, data, warrant, backing, rebuttal, and qualifier) within the TAP framework. Challenges were identified in both empirical and theoretical argumentation sessions, with specific terms denoting the session type where a challenge arises (e.g., empirical warrant or theoretical warrant). Regardless of the session type, PPTs aimed to support or refute the same claim, rendering the addition of "empirical" or "theoretical" to the claim element insignificant. It is crucial to recognize that challenges with one TAP element may indicate challenges with others. For instance, if a student presents invalid data, it suggests potential issues with the warrant. The study consistently coded challenges based on the primary element of concern, following this approach throughout.

4.1.1 Challenges of PPTs Acting as Learners in ADI Activities

This specific section addresses the challenges faced by PPTs when taking on the role of learners in the ADI activities. Challenges related to argumentation skills encompass the hurdles PPTs confront in formulating or presenting claims, empirical data, and empirical rebuttals. Figure 4.1 illustrates the particular challenges encountered by the PPTs during their involvement as learners in the ADI activities.

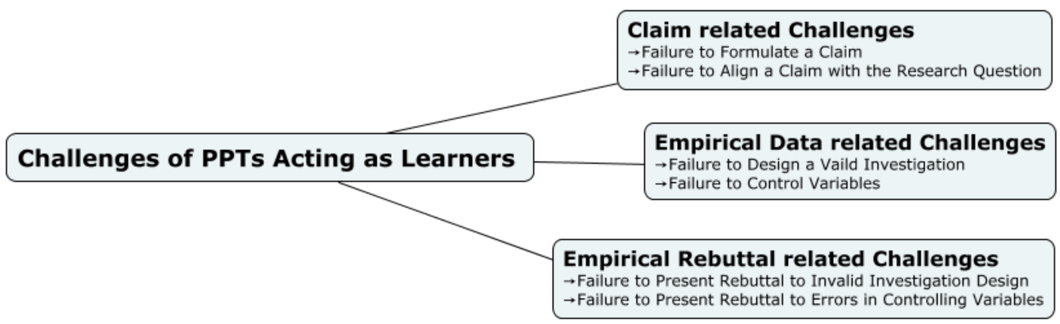


Figure 4.1. Challenges of PPTs acting as learners in ADI activities

4.1.1.1 Claim related Challenges

A claim represents an idea, assertion, or conclusion expressed by individuals and stands as the core element within the framework, as outlined by Toulmin in 1958. As per Padilla (1990), a hypothesis serves as a projection of the expected experiment outcome. In the context of the ADI, students initially formulate a hypothesis, which essentially serves as a claim derived from the past experiences and is meant to offer a potential response to the primary research question. The participants encountered difficulties when attempting to craft these claims as potential answers to the research questions. At times, the participants either refrained from crafting claims altogether or formulated claims that did not align with the research questions.

4.1.1.1.1 Failure to Formulate a Claim

The participants faced challenges while trying to formulate a claim as a potential response to the primary research question. Here is an illustrative example drawn from our data analysis:

Example:

The primary research question of the illumination activity was

- What are the factors affecting the illumination of a surface, how do they affect it?

The claim of Begüm's group was

- With an increase in luminous intensity, there is a corresponding rise in illumination.

In this case, the response provided partially addressed the primary research question, making it a potential candidate for a claim. Conversely, Begüm, in her reflective paper, noted that she initially struggled to formulate a claim and ultimately composed one with assistance from her group partner.

The question posed to Begüm in the reflective paper was

- What are your thoughts on the actions taken in the exploration step? Did you have preferences, concerns, areas of difficulty in understanding, or questions about why certain actions were taken? Please express your opinions clearly, providing reasons for your views.

Begüm's response was

- Honestly, I had a difficulty in constructing a claim at first. A lot of things took shape in my mind with the ideas of my friends. Then, I formulated a claim with the help of my group partner. Designing our investigation setups and experimenting was enjoyable. Working together with my partner by brainstorming ideas was instructive and developing.

This challenge was subsequently discussed in the pop interview, and the question was posed about the origin of this challenge as outlined in the following.

The researcher: What is the source of this difficulty?

Begüm: I think it is because our education system is based on memorization.

4.1.1.1.2 Failure to Align a Claim with the Research Question

The participants encountered challenges aligning with the primary research question in formulating a claim. Here is an example exemplified from our data analysis:

<u>Example:</u>

The primary research question of the shadows activity was

- What distinctions exist in the process of creating an umbra versus a penumbra?

The claim of Ece's group was

- As the distance between a point light source and an obstacle grows, the umbra's dimensions decrease.

In this specific case, the claim did not function as a response to the primary research question. This issue was revisited in the pop-interview with Ece. The conversation goes as follows.

> *The researcher:* In the reflection paper, you wrote that I had difficulty in constructing the claims and I constructed a claim that did not answer the research question, but I realized this while experimenting. What is the reason for constructing a claim that does not answer the research question?
>
> *Ece:* I believe the research question was exceptionally clear and precise. The obstacle in responding to this question was my unfamiliarity with the real-life significance of the term "penumbra." Although we encountered it in practice questions, the concept remained abstract as we had not witnessed an actual penumbra before. You sought distinctions between umbra and penumbra, but I lacked the knowledge of how to produce a penumbra. Consequently, my groupmate and I were uncertain about the formation of a penumbra, speculating that it might become visible as we adjusted our distance from or proximity to the light source.

While Ece does not encounter challenges in understanding the research question, it is observed that she struggles in articulating a claim. This difficulty arises from her lack of previous experience necessary for claim formulation.

4.1.1.2 Empirical Data related Challenges

Data refers to information, facts, or procedures utilized as proof to substantiate the claim, as defined by Toulmin in 1958. In the context of this study, empirical data pertains to data of either quantitative or qualitative nature that is gathered through investigations. The participants encountered difficulties in collecting credible data due to their inability to formulate a valid investigation and regulate variables during the exploration stages.

4.1.1.2.1 Failure to Design a Valid Investigation

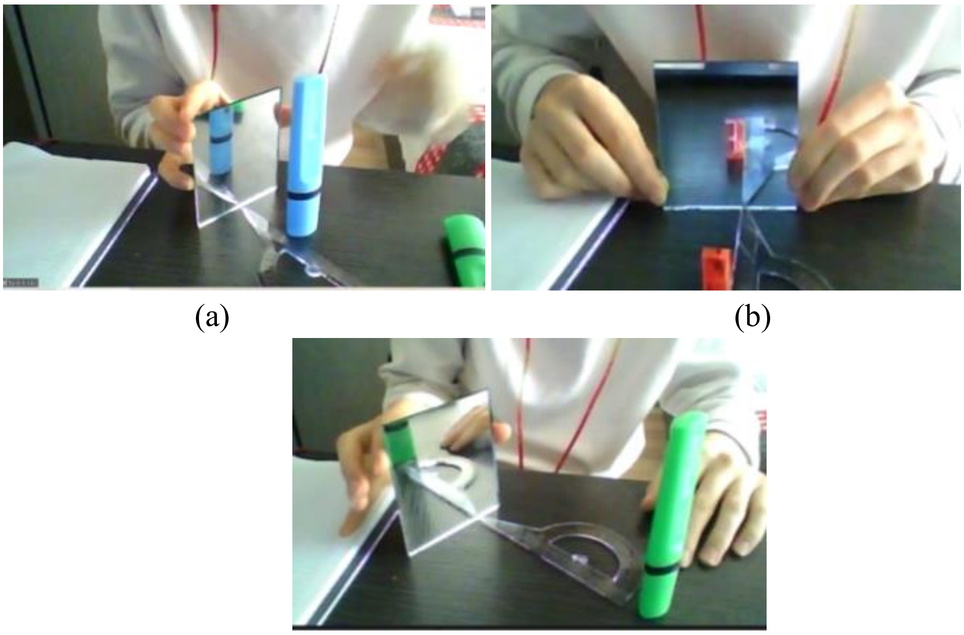
The participants encountered challenges in designing a valid investigation, leading to difficulties in collecting valid data. Consequently, this impacted their capacity to present accurate data during empirical argumentation sessions. The subsequent examples from our data analysis highlight this challenge:

<u>Example 1:</u>

The claim of Banu's group in image formation at the plane mirror activity was

- The object's distance from the plane mirror is equivalent to the distance of the image from the mirror.

The images provided as data can be observed in Figure 4.2.a, b, and c.



(a) (b)

(c)

Figure 4.2. Banu and the groupmate's experimental setup in the image formation at the plane mirror activity

In this instance, Banu and her groupmate attempted to gauge the distance of the image from the plane mirror by utilizing the ruler's image. It is evident that the participants had trouble designing a valid investigation.

The question posed to Banu related to this challenge in the reflective paper was

- What are your thoughts on the actions taken in the exploration step? Did you have preferences, concerns, areas of difficulty in understanding, or questions about why certain actions were taken? Please express your opinions clearly, providing reasons for your views.

Banu's response was

- My partner and I realized that it was wrong after we did the experiment, but we did not know how to set up an experimental setup for this claim.

Banu and her groupmate recognize the issue they are facing, but it is not appropriate to make a definitive statement about the exact cause. Nevertheless, from the researcher's observations, it can be inferred that this challenge arises from the participants' previous experiences. This is because the experiments conducted in Türkiye on image formation at a plane mirror are less complex than the experiments carried out in this research. Participants are attempting experiments that are new to them.

<u>Example 2</u>

Here is an excerpt from a dialogue between the teaching assistant and the participants during the exploration stage of the law of reflection activity.

> *Begüm:* We are currently in the process of preparing the experimental arrangement. Can you provide instructions on how to configure it?
>
> *The researcher:* What is your claim?
>
> *Begüm, Banu:* Angle of incidence equals to angle of reflection.

The researcher: Where are you sending the beam from, Banu?

Banu: I sketched the protractor on paper to facilitate data collection, and I directed it with an angle of incidence of 60 degrees. However, the ray did not make contact with the mirror (Figure 4.3).

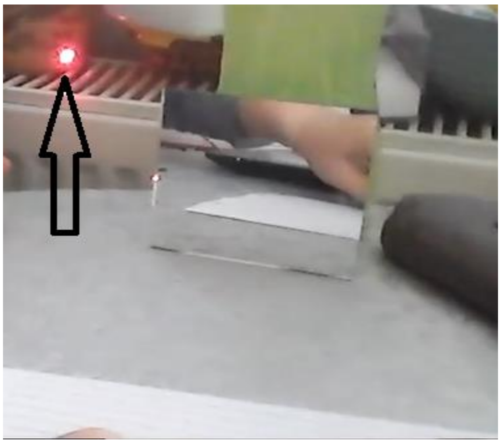


Figure 4.3. An image of Banu and Begüm's exploration stage of the law of reflection activity

Regrettably, the clarity of Figure 4.3 is insufficient given the reliance on Zoom for this study. For improved clarity, a black arrow is employed to mark the point of contact with the light. In this experiment, Banu and Begüm struggled with protractor usage, placing it at a considerable distance from the mirror. Consequently, they encountered challenges in reflecting the beam off the mirror and gathering data effectively.

4.1.1.2.2 Failure to Control Variables

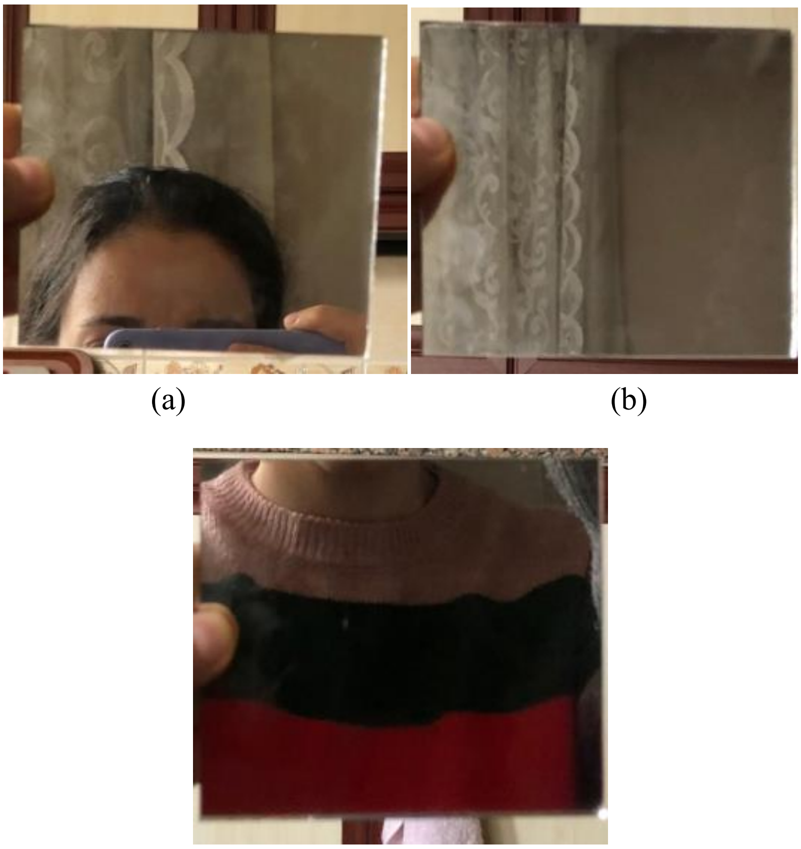
The participants faced challenges in controlling variables, impacting their ability to collect valid data. Consequently, this affected their capability to present accurate data during empirical argumentation sessions. Here are specific examples from our data analysis that illustrate this challenge:

Example 1:

The claim of Banu’s group in the field of view at a plane mirror activity was

- When the mirror is observed from various angles, the field of view at the mirror undergoes alterations.

The images provided as data can be observed in Figure 4.4.a, b, and c.



(a) (b)

(c)

Figure 4.4. Banu and the groupmate’s data in the field of view activity

When examining Figure 4.4, it is not immediately clear whether the data is valid. During the empirical argumentation stage, Banu was asked to explain her experimental setup. The sentence she used to describe it was as follows:

> *Banu:* I positioned the mirror in place, and then I viewed it from the standard upright position, followed by observing it while bending down, and finally, I

looked at it from a slightly elevated stance. I captured images of the mirror from these different angles.

From Banu's statement, it can be inferred that she not only observed the mirror from various angles but also adjusted her distance from the mirror simultaneously. In other words, she simultaneously manipulated both the independent and controlled variables, without properly controlling the latter variable. She failed to notice that, despite attempting a controlled experiment, she was altering two variables simultaneously.

Example 2:

The claim of Banu's group in the shadows activity was

- If there is only one light source in the environment, an umbra forms (on the screen behind the opaque object).

The image provided as data can be observed in Figure 4.5.

Figure 4.5. Banu and the groupmate's experimental setup in the shadows activity

During the exploration stage, Banu and her partner believed they were utilizing a single light source and detecting an umbra on the screen. However, in reality, they were employing two light sources and observing a penumbra on the screen. They did not consider that the Sun, which served as an additional light source, could impact the experiment's outcomes. Additionally, the light source they employed was not sufficiently distant to be considered a point source; instead, it was considered a circular light source. The count of light sources and the distance between the light source and the opaque object constituted variables that required proper control. As a result, the data they collected was invalid.

At the onset of the shadows activity, Banu and her partner devised an experiment involving adjusting the proximity of the light source to the opaque obstacle (Figure 4.6). Despite observing a penumbra on the screen, Banu remarked to her partner, "But it is not a penumbra; it is an umbra. The area of the umbra is getting bigger." This indicates a lack of full understanding of fundamental shadow concepts, including umbra, penumbra, point light source, spherical light source, etc., typically covered in high school. The deficiency in conceptual comprehension serves as a hindrance to regulating the distance variable of the investigation conducted in the exploration stage (Figure 4.5).

Figure 4.6. Banu and the groupmate's investigation at the onset of the shadows activity

4.1.1.3 Empirical Rebuttal related Challenges

A rebuttal is a statement that opposes any aspect of an argument, as defined by Toulmin in 1958. The participants encountered challenges when it came to noticing the invalid data presented by their peers during the empirical argumentation sessions. Consequently, the collected data must be required a rebuttal. However, due to their challenges in noticing flawed data, they also faced challenges when employing a rebuttal.

4.1.1.3.1 Failure to Present Rebuttal to Invalid Investigation Designs

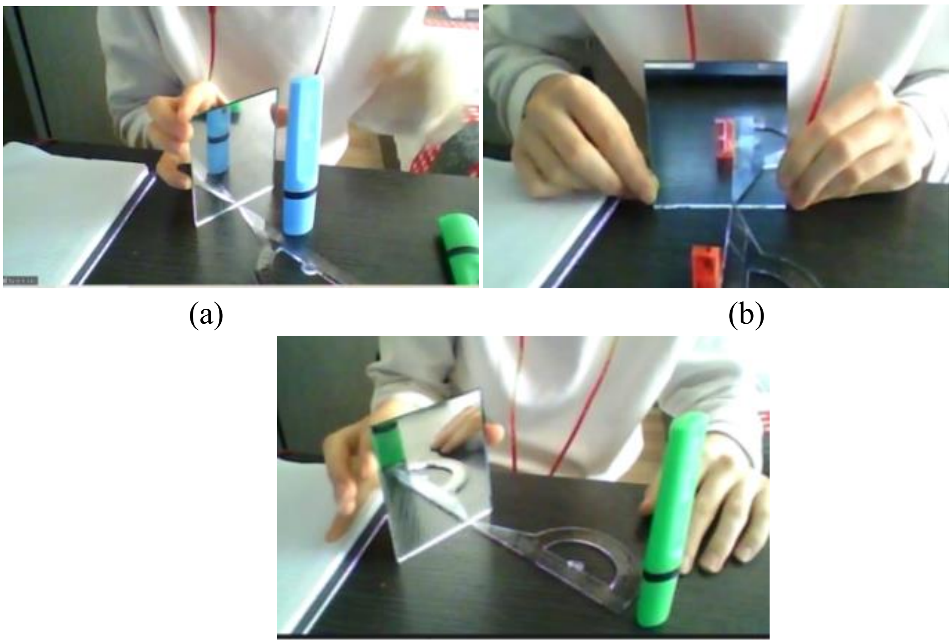
The participants encountered challenges in noticing invalid data resulting from problematic experimental designs throughout the investigation process. However, their difficulties in noticing such invalid data also impeded their capacity to present a rebuttal effectively. Here is a specific instance from our data analysis that exemplifies this challenge:

<u>Example</u>:

The claim of Banu's group in image formation at the plane mirror activity was

- The object's distance from the plane mirror is equivalent to the distance of the image from the mirror.

The images provided as data can be observed in Figure 4.2.a, b, and c.



(a) (b)

(c)

Figure 4.2. Banu and the groupmate's experimental setup in the image formation at the plane mirror activity

In this instance, Banu and her group partner attempted to gauge the distance of the image from the plane mirror by utilizing the ruler's image, resulting in invalid data. It is evident that Banu and groupmate had trouble designing a valid experiment, which in turn posed challenges in gathering valid data, subsequently giving rise to presenting valid data to support their claim. So, the rebuttal must be

- The data is invalid due to the flawed experimental design.

Beneath, a segment of the argumentative discussion pertaining to the image formation at a plane mirror activity of Banu and her group partner during the empirical argumentation session is presented.

> *The researcher:* Friends, in your opinion, can we trust the experiment conducted by Banu and Alin?
>
> *Begüm:* Actually, what Banu and Alin did seemed logical to me. For instance, if we consider that they placed the object at 3 cm, would not it naturally reflect at that same 3 cm point on the mirror? Similarly, when I placed an object at 5 cm, it also reflected at 5 cm, so we can observe that the distance remains consistent.

Begüm challenged with the interpretation of Banu and Alin's experimental design and could not pinpoint the error, which subsequently hindered her ability to present it as a rebuttal.

4.1.1.3.2 Failure to Present Rebuttal to Errors in Controlling Variables

The participants faced challenges in noticing invalid data arising from the simultaneous manipulation of two variables during the investigation process. However, their challenges in detecting such invalid data also hindered their ability to effectively present a rebuttal. Here are specific examples from our data analysis that illustrate this challenge:

<u>Example 1:</u>

The claim of Alin and Behin was

- The size of the penumbra we witness enlarges as the opaque object gets closer to the circular light source.

They utilized images of their data collection process as evidence. (Figure 4.7.a and b)

(a) (b)

Figure 4.7. Images captured during Alin and her groupmate's experiment

Alin and Behin not only adjusted the distance between the obstacle and the light source by moving the obstacle closer to the light source, but they also altered the distance between the obstacle and the screen. Therefore, they simultaneously modified two variables. So the rebuttal must be

- The data is invalid due to a lack of attention to the necessity of controlling the second variable.

Beneath, a segment of the argumentative discussion pertaining to the shadows activity during an empirical argumentation session is presented.

> *The researcher:* Alin and Behin, could you refresh our memory regarding your claim and provide an overview of your experiment?

Alin: We said "The size of the penumbra we witness enlarges as the opaque object gets closer to the light source." as the claim. We used a circular light source and an opaque obstacle in the experiment. We moved the obstacle closer to the source, moved it further away from the source, and observed the penumbra on the screen.

The researcher: Alin, do you believe that the data you gathered is reliable?

Alin: I gauged the separation between the obstacle and the light source, as well as the distance between the obstacle and the screen.

The researcher: So, everyone, do you believe that Alin managed to gather reliable data?

Canay: No, it is because Alin did not specify the extent to which they manipulated the distances. Furthermore, I am uncertain whether she consistently maintained the light source and the screen in a fixed position.

The researcher: I was present with them throughout the experiment. They did not move the light source and the screen at all; instead, they occasionally moved the obstacle.

Alin: I continuously measured the distances between the obstacle, the source, and the screen.

Canay: Okey, then. There is no problem.

The researcher: Friends, do you believe that Alin's experiment was flawless?

Dila: I believe the issue lies in the motion of the obstacle. When she moves the obstacle, she changes both the distance between the obstacle and the screen and the distance between the obstacle and the source. We conducted the same experiment but we kept the obstacle and the screen stationary, only manipulating the distance between the light source and the obstacle, ensuring that the distance between the obstacle and the screen remained constant.

The researcher: We heard about two experiments conducted to support the same claim. In your opinion, who do you think is correct in what they are saying, Alin or Dila?

Banu, Canay*:* Dila.

The researcher*:* Why?

Itır: Because Dila and her group partner did not simultaneously modify two variables. They conducted their experiment by altering only the independent variable.

None of the participants engaged in the argumentative discussion; only Banu was able to join later when another experiment, conducted correctly, was being explained.

The subsequent excerpt is from the dialogue between Banu and the researcher in the relevant pop-interview.

The researcher: In the pop-interview following the prior activity, the Illumination activity, concerning the argumentation sessions, you mentioned there were instances where you could not express your thoughts as intended. Did you encounter a similar challenge in the Shadows activity?

Banu: No, I did not face the same issue. This week, regardless of my certainty in my knowledge, I expressed my thoughts openly.

It is evident to note that Banu’s inability to participate in the argumentative discussion was not due to hesitation but rather because she did not notice the error in the data collection process until a correctly conducted experiment was being explained. Consequently, she had difficulty challenging it using rebuttal.

Example 2:

The claim of Banu and İlke was

- In the presence of two light sources in the surroundings, we can observe both penumbra and umbra on the screen situated behind the opaque object.

They utilized image of their data collection process as evidence. (Figure 4.8)

Figure 4.8. Image captured during Banu and İlke' experiment

The following excerpt is from the argumentative discussion that occurred in the empirical argumentation stage of the shadows activity.

> *The researcher:* İlke, can you share your claim with us?
>
> *İlke:* In the presence of two light sources in the surroundings, we can observe both penumbra and umbra on the screen situated behind the opaque object.
>
> *The researcher:* Friends, do you believe this experiment is accurate? In this setup, they have two light sources and an opaque obstacle, and they say that they observed both umbra and penumbra on the screen. Is this claim correct?
>
> *Begüm:* Yes, I think it is true because we have conducted the same experiment and seen the same thing.

The researcher: Banu (groupmate of İlke), can you show us the experimental setup? Begüm, why do you think it is true?

Begüm: Because when we held the two light sources close enough to connect them, we saw an umbra in the center and a thin penumbra around it. Then, when we moved the light sources apart, we saw two penumbrae.

The data is invalid since the daylight is also another light source that needs to be controlled. Due to the influence of natural daylight on the experiment's results, Banu and Ilke were unable to observe an umbra on the screen at any point. So the rebuttal must be

- The data is invalid due to a lack of attention to the necessity of controlling the existence of daylight.

Begüm had the same challenge as Banu's group and failed to identify the mistake in the data collection procedure, leading to her struggle in presenting it as a rebuttal.

4.1.2 Challenges of PPTs Integrating ADI into the Turkish Physics Curriculum

This specific section is related to the difficulties faced by the PPTs when incorporating the ADI into the Turkish physics curriculum. The participants opted for various objectives for the ADI activities they would create and carried out research aligned with their chosen objectives. Due to the challenges they encountered, each participant selected one objective from among them. The finalized agreed-upon objectives and the articulated research questions are outlined below.

The objective of Begüm's ADI activity was

- Students examine the factors influencing the resistance of a solid conductor.
  a) They establish connections between variables using experiments or simulations and formulate a mathematical model. Mathematical calculations are not included.

b) The changes in conductor resistance due to temperature variations and the interpretation of resistance using color codes are excluded.

The research questions of Begüm's ADI activity were

- What are the factors affecting the resistance of a solid conductor, and in what ways do they impact? What underlies the theory behind your response?

The objective of Banu's ADI activity was

- Students investigate the factors influencing torque.
  a) Students draw conclusions about the variables affecting torque through experiments or simulations.

The research questions of Banu's ADI activity were

- Which is the simpler option for performing push-ups: with knees or on toes, and why? What underlies the theory behind your response?

The objective of Ece's ADI activity was

- The student clarifies that the buoyant force on objects in still fluids is a result of the difference in pressure forces.
  a) Archimedes' Principle is elucidated, involving a comparison of the magnitudes of the buoyant force and the object's weight in scenarios involving floating, suspension, and sinking.
  b) An outline of the mathematical model for buoyancy is presented, although specific mathematical calculations are not included.

The research questions of Ece's ADI activity were

- What are the factors affecting buoyancy, and in what ways do they impact? What underlies the theory behind your response?

Upon analyzing the data collected during their experiences in preparing ADI materials, it became evident that the participants faced challenges regarding formulating theoretical data and theoretical warrant in the development of ADI materials. The particular challenges experienced by the participants in the preparation phase are presented in Figure 4.9.

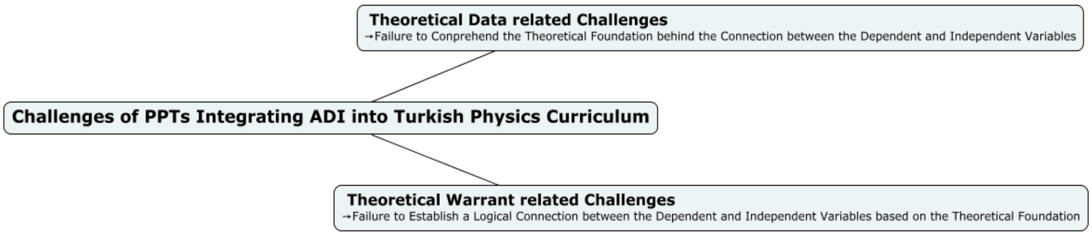


Figure 4.9. Challenges of PPTs Integrating ADI into the Turkish physics curriculum

4.1.2.1 Theoretical Data related Challenges

According to Toulmin's 1958 definition, data includes information, facts, or procedures used as evidence to bolster a claim. In the scope of this research, theoretical data refers to facts or information that forms the theoretical foundation underpinning the connection between variables. This information is embedded in the explanation stage. The participants struggled to understand the theoretical basis underlying the connection between the dependent and independent variables.

4.1.2.1.1 Failure to Comprehend the Theoretical Foundation behind the Connection between the Dependent and Independent Variables

The participants struggled to understand the theoretical basis that forms the connection between the dependent and independent variables, which is referred to as theoretical data. An illustrative example from our data analysis highlights this challenge.

Example

The theoretical data Begüm incorporated in the explanation stage of the ADI activity does not provide an adequate theoretical foundation for explaining the relationship between the variables affecting the resistance of a solid conductor. The theoretical data given in Begüm's ADI activity was

- All matter consists of atoms, and when electrons within a conductor are part of an electrical circuit, they interact with atoms as they attempt to advance in their path.

This statement is correct, but it lacks completeness. For completeness, it should be as follows.

- Electrical resistance is primarily caused by the collisions of electrons with atoms and other electrons within a material. As electrons move through a conductor, they interact with the atomic structure of the material. These interactions, which include collisions with atoms and other electrons, impede the flow of electrons and give rise to resistance. The phenomenon is a result of the opposition that the material presents to the movement of electric current.

The data that must be presented at the explanation stage was

- Electrical resistance is primarily caused by the collisions of electrons with atoms and other electrons within a material.

This suggests that Begum has not completely understood the theoretical basis for elucidating the connection between the variables influencing the resistance of a solid conductor. This situation became even more apparent in the 'Challenges of PPTs

Acting as Teachers' stage. Begüm's struggle with conceptual understanding also led to challenges in presenting theoretical data.

4.1.2.2 Theoretical Warrant related Challenges

As per Toulmin's 1958 definition, a warrant serves as the link connecting data to a claim by elucidating how and why the data supports the claim. In the context of this study, theoretical warrant pertains to the connection between variables grounded in a theoretical foundation. Participants faced challenges in establishing this connection based on theoretical foundations.

4.1.2.2.1 Failure to Establish a Logical Connection between the Dependent and Independent Variables based on Theoretical Foundation

While participants did not experience issues with the theoretical data itself, they encountered challenges in formulating the theoretical warrant for the connection between variables based on that theoretical data. A specific example from our data analysis highlights this particular difficulty.

<u>Example</u>

Here is a segment from the post-writing interview held with Ece.

> *The researcher:* Did you encounter any challenges or issues while composing the theoretical argumentation stage?
>
> *Ece:* I faced a challenge because I mixed up justifications with conclusions in my own thoughts.

One of the claims in the Ece's ADI activity was

- With the augmentation of gravitational acceleration, buoyancy also increases.

The theoretical data given by Ece in the explanation stage was

- The buoyant force applied to an object by the fluid results from the variance in pressure forces acting on the object from above and below.

And the theoretical warrant composed by Ece was

- With an increase in gravitational acceleration, the buoyant force will also rise. In reality, for the object's net force to be zero, there needs to be a buoyant force proportional to the weight of the object.

The theoretical warrant was supposed to be

- As gravitational acceleration increases, the difference in pressure forces above and below the object grows, resulting in an increased buoyant force.

In this case, the statement written by Ece as a theoretical warrant is neither false nor a justification because it lacks the necessary theoretical data. The assertion that the object remains in equilibrium when the net force on it is zero is a consequence, not a cause, of the change in the magnitude of the buoyancy force. In this context, the theoretical data should be the cause. As Ece acknowledged during the interview, she struggled with distinguishing cause-and-effect relationships.

4.1.3 Challenges of PPTs Acting as Teachers in ADI Activities

This specific section focuses on the challenges that arise when the PPTs take on the role of instructors in the ADI activities. The challenges during the teaching phase involve the hurdles that the PPTs encounter while presenting, guiding or questioning claims, empirical data, empirical warrants, theoretical data, and theoretical warrants.

Figure 4.10 visually represents the specific challenges encountered by the participants while serving as teachers in the ADI activities.

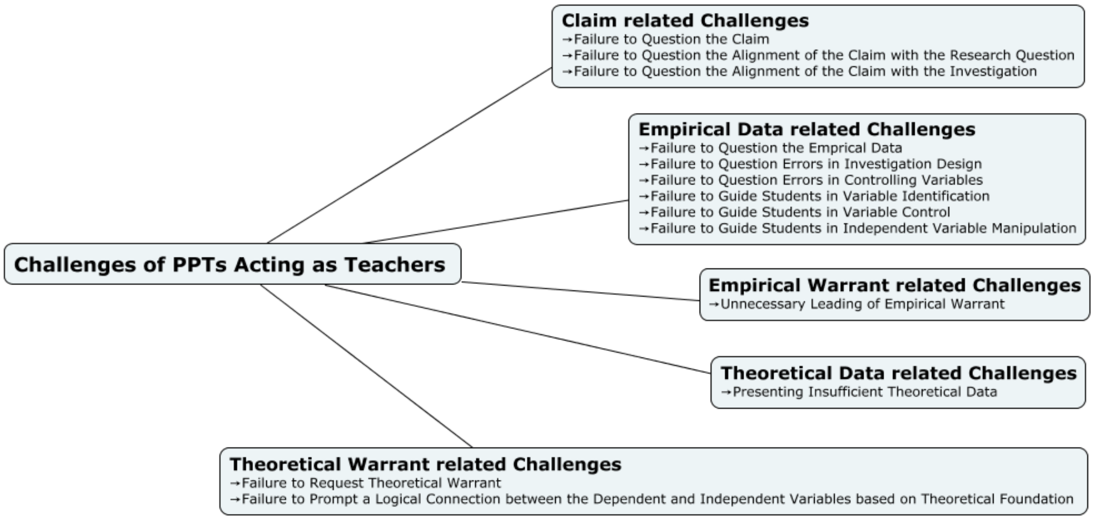


Figure 4.10. Challenges of PPTs acting as teachers in ADI activities

4.1.3.1 Claim related Challenges

A claim, as defined by Toulmin in 1958, is an idea, assertion, or conclusion central to the framework. According to Padilla (1990), a hypothesis acts as a projection of the anticipated outcome in an experiment. In the ADI conducted in this study, students first develop a hypothesis, essentially functioning as claims drawn from their prior experiences, aimed at providing a potential answer to the primary research question. The participants faced challenges in scrutinizing the presence of a claim, as well as the alignment of the claim with both the research question and the investigation.

4.1.3.1.1 Failure to Question the Claim

In instances where the students of the participants discussed the investigation process, serving as an empirical warrant for this study without articulating their claims, there were occasions when the participants failed to recognize the absence of the claim. This led to a lack of inquiry into its existence. To illustrate this concern, a specific instance from the data analysis is provided:

Example

The conversation during the empirical argumentation session of Begüm's peer teaching session unfolds in the following manner.

> *Canay:* We had three claims. Initially, we examined the impact of resistivity. To do this, we maintained constant length and cross-sectional area, mirroring Itır and her partner's approach, which enabled us to isolate the influence of resistivity on resistance. Subsequently, we applied a similar method to length and cross-sectional area. We held resistivity and cross-sectional area constant while varying length, and we kept length and resistivity constant while adjusting cross-sectional area.
>
> *Begüm:* Very good, do you agree with Canay?

In this case, there is no statement available for agreement, as Canay is merely outlining the process. To clarify, Canay did not elaborate on the specific claims being made, and Begüm did not inquire about the presence of any claims. In essence, Begüm raised a challenge by noticing the absence of a clear claim and thus questioning it.

4.1.3.1.2 Failure to Question the Alignment of the Claim with the Research Question

In accordance with the ADI, the claim presented should serve as the response to the primary research question. Instances arose where the claims made by the participants' students deviated from the research question, and in certain cases, the participants did not scrutinize such occurrences due to a lack of awareness. An illustrative example from our data analysis is as follows:

Example

Here is an excerpt from Banu's interaction with her students during the empirical argumentation session of her peer teaching.

Banu: Is there anyone willing to present their claim to the class?

Itır: We suspended the bag from our arm while keeping our arms parallel to the ground. Initially, our claim was that we would experience increased torque on our arm as the bag's distance from the support point increased. This claim was indeed substantiated when we hung the bag at various positions along the arm. We detected the greatest force when the bag was suspended at the wrist.

Banu: Have any of our fellow students attempted to test the claim that increased torque would be experienced on the arm that is parallel to the ground as the bag's distance from the support point increased?

In this specific example, the data collected aligns with the students' claim and is relevant to the subject being taught. The issue for Banu in this context is her failure to recognize that the students' claim is not formulated as a response to the primary research question, and therefore, she does not inquire about it.

4.1.3.1.3 Failure to Question the Alignment of the Claim with the Investigation

Following the ADI, it is essential to conduct an investigation that substantiates the presented claim. Instances occurred where the claims put forward by the participants' students did not correlate with the investigation the students were conducting, and in certain situations, the participants did not scrutinize such occurrences due to a lack of awareness. An illustrative example from our data analysis is as follows:

<u>Example</u>

Here is an excerpt from the empirical argumentation stage of Ece's peer teaching.

Ece: Let us see who did what. I think Begum and Canay concentrated on the effect of the submerged volume on the buoyancy. Can you share your actions with us?

Canay: We experienced some confusion in our experiment. We possessed wooden blocks with varying masses of 2, 4, and 5 kilograms, all constructed from the same material. As the masses differed, we claimed that when buoyancy increased, the volume submerged beneath the water's surface would also increase. To test this claim, we successively immersed the 2 kg, 4 kg, and 5 kg objects in water and observed a clear and proportional rise in both buoyancy and the volume submerged.

Ece: Are you of the opinion that there might be an issue with the experiment carried out by Canay and her groupmate?

İlke: We also explored how the volume of submersion affects buoyancy, albeit through a distinct approach. We immersed a wooden block into a liquid with a density of 2 units, keeping its volume and weight constant throughout. Our sole manipulation involved gradually lowering it with a device, not altering its physical characteristics. Remarkably, our findings mirrored those of the prior experiment: as the volume of submersion increased, so did the buoyancy.

Ece: Do you believe that the experiment carried out by Ilke and her partner can be considered a trustworthy or dependable one?

Canay, Itır: Yes.

Ece: Alright, Banu and Dila conducted an experiment where they altered the liquid's density. Could you please provide information about your findings?

Canay and Begüm claimed that as buoyancy increased, the submerged volume beneath the water's surface would correspondingly increase. As evident from Canay and Begüm's investigation, they essentially attempted to alter the submerged volume and explored its impact on buoyancy. In reviewing Canay and Begüm's claim, it is apparent that the dependent variable and independent variable are interchanged. Ece failed to notice this and thus questioning the claim.

4.1.3.2 Empirical Data related Challenges

Data, as outlined by Toulmin in 1958, constitutes information, facts, or procedures employed as evidence to support a claim. In the context of this study, empirical data encompasses both quantitative and qualitative data gathered through investigations. This section encompasses the participants' difficulties in questioning the empirical data, errors in the investigation design, and the variable control. Additionally, it involves guiding students, where challenges arise from the participants' own difficulties in variable identification, variable control, and manipulation of the independent variable.

4.1.3.2.1 Failure to Question the Empirical Data

Instances occurred when the students of the participants introduced claims without referencing empirical data and empirical warrants. Unfortunately, on some occasions, the participants failed to realize this, resulting in a missed opportunity to discuss the validity and reliability of that data. To exemplify this concern, specific examples from the data analysis are provided:

Example 1

The discussion in the empirical argumentation stage of Begüm's peer teaching experience proceeds as follows:

> *Begüm:* Ilke, please share with us what you have experimented with, your claim, and the outcomes you have achieved.
>
> *İlke:* We investigated the impact of length on resistance. Initially, we claimed that increasing the length would lead to a decrease in resistance. However, our experimental findings contradicted our expectations. It turned out that as we increased the wire's length, it exhibited the opposite behavior. We anticipated that greater length would result in less resistance as if it would facilitate the passage of current more easily.

Begüm: Prior to conducting the investigation, you held the belief that the material exhibited greater resistance to electricity when its length was shorter.

İlke: That was our assumption, but the actual outcome did not align with it.

Begüm: That is the reason, my friends, why conducting experiments and simulations is truly enjoyable. Sometimes, our preconceived notions do not match reality, and it is fascinating to observe the differences. Thank you for sharing, Ilke. Now, Lara, can you tell us about your experiment?

In this case, Begüm faced difficulties in attending to the data collected. Begüm did not initiate a discussion about the data in İlke and her groupmate's investigation. Additionally, she did not create an opportunity for her classmates to provide rebuttals if they encountered flawed data.

Example 2

Here is an excerpt from Banu's interaction with her students during the empirical argumentation stage of her peer teaching.

Banu: Is there anyone willing to present their claim to the class?

Itır: We suspended the bag from our arm while keeping our arms parallel to the ground. Initially, our claim was that we would experience increased torque on our arm as the bag's distance from the support point increased. This claim was indeed substantiated when we hung the bag at various positions along the arm. We detected the greatest force when the bag was suspended at the wrist.

Banu: Have any of our fellow students attempted to test the claim of that increased torque would be experienced on the arm that is parallel to the ground as the bag's distance from the support point increased?

In this specific example, Itır presented and elucidated the experiment they conducted. Itır refrained from discussing her data and its collection method. Banu's shortcoming stems from her failure to pose a question that could initiate a conversation regarding her students' data or the experimental process. This action by Banu hindered the potential for an argumentative discussion and prevented her students from offering a rebuttal in the event of encountering flawed data.

4.1.3.2.2 Failure to Question Errors in Investigation Design

This challenge encompasses situations where participants overlooked mistakes made by their students in designing investigations, resulting in a failure to question these errors. A concrete example from our data analysis illustrates this issue:

<u>Example</u>

Here is a portion of Banu's communication with her students in the empirical argumentation session of her peer teaching.

> *Banu:* Have any of our fellow students attempted to test the claim of that increased torque would be experienced on the arm that is parallel to the ground as the bag's distance from the support point increased?
>
> *Lara,* İlke*:* We did.
>
> *Banu:* What have you observed?
>
> *İlke:* Teacher, we employed three different weights: a half-liter bottle with full of water, a 1 kg dumbbell, and a 2 kg dumbbell. For each case, one arm was maintained parallel to the ground, and an attempt was made to hold it steady with the weights. We also experimented with placing the weights inside the elbow and overlapping the lower arm over the upper arm, essentially squeezing the inner elbow. We still maintained the arm parallel to the ground. It was notably more challenging to maintain the position of the arm when the arm was extended. Furthermore, we attempted the same with a

4 kg dumbbell and found it impossible to lift when the arm was fully extended. However, when we used the inside of the elbow we managed to lift it.

Banu: What are your thoughts on the experiment conducted by Ilke and Lara? Can we consider it as valid?

Itır: I am not quite clear on how they grip the dumbbell.

Canay: However, it is possible that the way you are positioning your arm might also offer some support, potentially making it more manageable to hold. I cannot be entirely certain.

Itır: For instance, if you were to attach a rope to the dumbbell and suspend it from your elbow, would it produce the same outcome as when you close the elbow?

İlke: I thought it would.

Behin: She would need to apply more force because, as the arm bends at the elbow, the center of mass of the lower arm would be nearer to the pivot point.

Banu: In fact, İlke and Lara simultaneously experimented with something else. They mentioned that they tested a half-liter water bottle, a 1 kg dumbbell, and a 2 kg dumbbell. What distinctions did you notice among these items?

In this instance, İlke and Lara, while investigating the impact of the lever arm's length on torque, unintentionally shorten the lever arm both by shortening the arm and by simultaneously bringing the weight closer to the pivot point. They essentially reduce the lever arm's length in two different ways simultaneously. Although it may not appear to be an issue, it actually poses an investigation design challenge. As Banu did not notice the challenge posed by İlke's group, it is significant that Banu redirects her attention to another claim made by İlke and her partner without scrutinizing this challenge.

4.1.3.2.3 Failure to Question Errors in Controlling Variables

This challenge includes the instances that occurred when the participants failed to observe errors made by their students in controlling variables, consequently neglecting to inquire about these errors. Here is a specific example gleaned from our data analysis:

Example

During Banu's first high school teaching, a group comprising two individuals presented the following claim.

- Performing push-ups on your knees is simpler because it decreases the weight involved, allowing for a more comfortable execution of the exercise.

The interaction between Banu and the students who presented this claim during the exploration stage unfolds as follows.

> *Banu:* What did you guys do, what did you try?
>
> *Alp:* Teacher, for the initial experiment, I actually had a similar idea. We always had the weight on our wrists, and first, I attempted to raise my arm straight by moving it from my shoulder. Then, with the weight still on my wrist, I tried to lift my arm using only my elbow, without moving my upper arm. It is almost like the elbow is acting as the knee in the push-up scenario. I find it quite similar to the push-up example.
>
> *Banu:* What were your sensations or experiences during this experiment?
>
> *Alp:* Lifting with our elbow was more effortless. This was because we had to support the weight of the entire arm in addition to the extra weight when lifting from the shoulder.

Banu: So, what factor are you investigating here?

Alp: I am examining the scenario of performing push-ups on the knees, as the weight of our lower legs is not involved.

Banu: So, you are investigating how weight impacts torque.

Akay: No, teacher, the factor is not weight. He is suggesting that it both increases and decreases the distance to the pivot point.

Banu: His actual thought process is as follows: When I lift from the elbow, only the weight of the lower arm affects the torque. However, when I lift from the shoulder, the weight of the entire arm affects the torque. He actually wants to discuss this aspect.

The exchange between Banu and the students who put forth this claim in the empirical argumentation session is described as follows.

Banu: Alp, could you please explain what you carried out in your investigation?

Alp: The weight was consistently placed on our wrists. First, we lifted our wrists with our arms fully extended. Then, with the weight still on our wrist, we lifted it using our elbow without any movement in the upper part of our arm. It felt easier when we lifted it from the elbow. This was because when we did not involve the upper part of our arm, there was no extra weight, and it also demonstrated that we did not engage the lower part of our legs when doing push-ups on the knees.

Banu: Baran, you conducted an investigation to examine how the angle affects torque. Would you mind sharing your findings and experiences regarding the angle factor?

In this case, the demonstration experiment conducted by Alp and Akay raises some concerns. They simultaneously manipulated both the weight and length variables. Furthermore, the control of the angle variable does not appear to be adequate. During the exploration stage, Akay referred to the independent variable as length, while Alp mentioned weight. Despite this inconsistency, Banu did not identify her students' issue with manipulating variables simultaneously by not taking into variable control. Consequently, the students were unable to gather valid data in the exploration stage, and thus the data they presented during the empirical argumentation stage lacks validity. It appears that Banu did not attend this challenge and inquire about the validity of the data.

4.1.3.2.4 Failure to Guide Students in Variable Identification

This challenge involves instances where participants' students do not commit errors in variable control, but the participants misguide them due to their own difficulties in identifying variables. Here is an illustrative example drawn from our data analysis:

<u>Example</u>

The data section of the activity sheet completed by Itır and Lara as part of Ece's peer teaching is shown below.

Table 4.1. Emprical data of Itır and Lara

Density of the object (K/L)	**Density of the liquid (K/L)**	**Buoyancy force (N)**	**Volume of the object (L)**
0.40	0.50	19.60	5
0.40	1	19.60	5
0.40	1.20	19.60	5
0.40	1.50	19.60	5

Feedback from Ece on this table was

- The experiment was conducted improperly. Given that the object's density is lower than that of the liquid, it remains afloat. Consequently, variations in the density of the liquid lead to alterations in the object's submerged volume, making it challenging to observe changes in buoyancy. In reality, two variables were simultaneously altered by adjusting both the object's submerged volume and the density of the liquid.

The experiment was sound, as illustrated by this example. The issue lied in Ece's feedback, where she mistakenly attributed a problem. Itır and Lara did not manipulate two variables simultaneously; they solely adjusted the density of the liquid and observed the corresponding change in the submerged volume. Ece, however, interpreted the submerged volume as a variable requiring control, rather than recognizing it as a dependent variable. In this context, Ece faced challenges stemming from her struggles with variable identification. This challenge led to a misinterpretation of the students' data.

4.1.3.2.5 Failure to Guide Students in Variable Control

This difficulty arises in situations where the participants' students effectively manage variable control without making errors, but the participants inadvertently guide them incorrectly due to their own struggles in controlling variables. Here is a concrete example extracted from our data analysis:

<u>Example</u>

Ece's dialogue with her fellow students in one of the breakout rooms while her peers were engaged in their investigation during the exploration stage of her peer teaching was

> *Ece:* Is there a problem?
>
> *Begüm:* How can we create two distinct volumes of an identical substance?
>
> *Ece:* Do the substances you place in the water need to be identical? Do you submerge the wooden block in the water? What amount of the volume do you notice submerging?

Canay: 5L

Ece: And what is the buoyancy force acting on it?

Canay: 49N

Ece: Alright, remove the wooden block, and immerse the brick in the water.

Canay: Submerged volume is 2.5L.

Ece: And what is the buoyancy force acting on it?

Canay: 24.5N

Ece: Is buoyancy the sole factor in action in this situation?

Canay: The brick sank because it possessed greater density than water, making it beyond the capacity of buoyancy to keep it afloat.

Ece: And what are we examining?

Canay: Effect of submerged volume. Is it possible to carry out the investigation in this manner?

Ece: Yes.

In this case, Ece's students were hesitant to simultaneously alter the volume of submersion and the density of the object they submerged in water, so they sought Ece's guidance. However, Ece proposed conducting the experiment by simultaneously modifying two variables. It is common knowledge that the object's density does not impact buoyancy, but due to the scientific inquiry process, during the exploration stage, students are typically advised to modify only the independent variable while maintaining all other factors constant. It is quite evident that Ece is encountering a challenge in variable control due to her own challenge.

4.1.3.2.6 Failure to Guide Students in Independent Variable Manipulation

This difficulty entails the participants providing inaccurate guidance to their students regarding the manipulation of the independent variable in the investigation.

<u>Example</u>

In the empirical argumentation session of her peer teaching, Banu's students debated the impact of the length of the lever arm and force on torque. However, they did not address the angle between the force and the lever arm. Subsequently, the ensuing conversation transpired between Banu and her students at the same stage.

> *Banu:* Do we require an additional claim to respond to the research question regarding whether another factor can influence torque?
>
> *Canay:* I have no idea.
>
> *Banu:* In what manner does the angle between the force and the lever arm impact?
>
> *Itır:* For instance, if we suspend the bag at an angle other than perpendicular to the ground, I am not quite clear about what you mean by "angle".
>
> *Banu:* For instance, we held the bag in our hands, demonstrating it like this (Banu lifted the bag by raising her arm from the shoulder approximately 10-15 degrees from a position parallel to the ground without bending her elbow) and like this (Banu lowered the bag by lowering her arm from the shoulder approximately 10-15 degrees from a position parallel to the ground without bending her elbow).

Following Banu's explanations, the students proceeded to conduct the demonstration experiment. In this instance, Banu provided insufficient and inaccurate details about the demonstration experiment. She demonstrated the experiment twice using her arm, and in both demonstrations, the angle between the force and the lever arm remained the same. Given that this demonstration experiment relies on sensory perception, it is crucial to carry out the experimentation with great care. To gather meaningful data, one measurement should be taken with the arm parallel to the ground, while the other measurements should consistently occur either above or below the arm’s parallel position. Furthermore, there should be substantial differences in the angle values measured to distinctly discern in which position the arm experiences more strain. It is evident that Banu encountered challenges in handling the independent variable associated with experimenting, particularly in terms of manipulating the variable effectively.

4.1.3.3 Empirical Warrant related Challenges

According to Toulmin’s 1958 definition, a warrant acts as the connection between data and a claim, explaining the reasons and ways in which the data supports the claim. In this study, empirical warrant specifically addresses the validity and reliability of empirical data. The participants encountered difficulties in indirectly probing the aspects related to the empirical warrant.

4.1.3.3.1 Unnecessary Leading of Empirical Warrant

This challenge involves an excess of directive guidance in the argument-driven questioning of empirical warrants. Here is a specific example derived from our data analysis:

<u>Example</u>

The claim of Itır and her partner in Begüm’s peer teaching was

- When the resistivity of the substance increases, its resistance increases too.

The provided passage was extracted from the dialogue between Begüm and her students in the empirical argumentation session of her peer teaching experience.

> *Itır:* Our intention was to investigate the connection between resistivity and resistance and to do so, we maintained a constant cross-sectional area and length while examining the resistance of materials across 5 distinct resistivity

values, as seen on the screen. What we observed was that as the resistivity of the material increased, the resistance increased.

Begüm: Friends, what are your thoughts on the experiment conducted by Itır and her partner? Personally, I find it quite impressive. What are your opinions on the reliability of their data? For instance, during the experiment, did you notice any factors, such as changes in length occurring simultaneously and consistently? Or do you believe it was a well-executed experiment?

Canay: Did Itır and her partner not investigate how resistivity impacts resistance?

Begüm: Yes, they investigated how resistivity impacts resistance.

Canay: What is the reason for altering the length? I am puzzled by that.

Begüm: That is precisely the question I had in mind. Do you believe such modifications are necessary? I mean, for instance, why do you think they adjusted the resistivity while keeping the cross-sectional area and length constant, without simultaneously adjusting the cross-sectional area or length at a consistent rate? Their observation, as you mentioned, pertains to the influence of resistivity on resistance. Therefore, did you apply a similar approach to the factor you were investigating? What were your claims?

In this case, it is clear that Begüm provided an overabundance of directional guidance of empirical warrant, which contradicts the principles of inquiry-based learning. Instead of actively engaging other students in the class by asking a question like, “Is your friend’s result reliable?” she explicitly inquires about variable control, effectively concluding the discussion.

4.1.3.4 Theoretical Data related Challenges

As per Toulmin’s definition in 1958, data comprises information, facts, or procedures employed as supporting evidence for a claim. In the context of this study, theoretical data denotes facts or information that establishes the theoretical foundation supporting the relationship between variables. This section encompasses the difficulties faced by the participants in presenting the theoretical basis linking the variables.

4.1.3.4.1 Presenting Insufficient Empirical Data

The participants did not understand the theoretical foundation behind the connection between variables, and they struggled to articulate this foundation during the explanation stage. Consequently, they did not notice when their students presented claims without referencing theoretical data, and the participants faced challenges in questioning the theoretical foundation. A specific example from the data analysis is provided to illustrate this concern.

Example

The theoretical data presented by Begüm at the explanation stage was

- All matter consists of atoms, and when electrons within a conductor are part of an electrical circuit, they interact with atoms as they attempt to advance in their path.

In this instance, the theoretical data presented by Begüm, fell short of being comprehensive. To make it sufficient, she should have elaborated on resistance at the micro level, elucidating that the resistance of substances to electric current results from the collisions between conduction electrons and intrinsic particles within the material, such as atoms. As a result, she had data related challenges as discussed in the challenges of PPTs integrating ADI into the Turkish physics curriculum section. While she can articulate the concept of resistance at the macro level, she struggles to elucidate the micro-level understanding, which constitutes the theoretical foundation linking the variables.

Begüm proceeds the theoretical argumentative discussion of her peer teaching in a subsequent manner.

Begüm: Now, friends, I encourage you to rethink your thoughts and observations. I would like a few of our peers to recap the points we have covered thus far, and I pose the question once more: What, in your opinion, are the elements that influence a solid conductor's resistance? Friends, I am curious to know: upon what does resistance truly rely?

Canay: Allow me to share one of them. The resistance of a conductor is contingent upon the conductor's length, exhibiting a direct correlation. With an increase in length, the electron mobility within becomes progressively restricted, resulting in an elevated resistance. This is because resistance functions as a restraining factor on electron movement, and the longer the wire, the more constrained the electron motion becomes. Hence, there exists a direct proportionality between them.

Begüm: That is excellent. Ece, could you please identify another factor influencing resistance?

In this specific example, Begüm did not notice whether Canay's response contained the theoretical data. Consequently, Begüm encountered obstacles when questioning her peers regarding theoretical data, and therefore theoretical warrant and theoretical rebuttal in the discourse.

As the theoretical argumentation session of Begüm's peer teaching nears its conclusion, there is an exchange between Begüm, Itır, and Behin in the following manner.

Itır: We have observed that an increase in resistivity results in higher resistance. When we inquire about the reasons for the rise in resistance, based on the information you have provided, it stems from the unique arrangement of atoms and molecules within each substance. As electrons traverse through it, the greater their encounters with these atoms, the more collisions they undergo. In other words, the more congested their path becomes, the greater their resistance. This, in turn, leads to elevated resistivity and overall resistance, given a consistent length and cross-sectional area.

Begüm: Yes, thank you Itır.

Behin: Professor, I do not entirely concur with Itır. Did not we discuss that elevating the count of free electrons leads to reduced resistivity? In other words, we established that a decrease in the number of free electrons results in lower resistivity. Is not it, in fact, the quantity of free electrons that holds more significance than the atomic and molecular arrangement when considering the impact on resistivity?

Begüm: Free electrons play a crucial role in the generation of electrical current. However, in a similar manner, for instance, the atomic configuration of carbon differs from that of copper, and it influences the arrangement of atoms similarly.

In the dialog between Begüm, Itır, and Behin, Begüm's inability to provide a satisfactory response to Behin's question serves as evidence that Begüm lacks a deep conceptual understanding of the theoretical foundation behind the connection between the variables. In the explanation stage, Begüm omits the formation of resistance through electron and atom collisions. In contrast, Itır mentions collisions, possibly drawing from her prior knowledge. Behin disagrees with Itır, attempts to use Begüm's information to create a warrant, and concludes with a question. Begüm struggles to provide a meaningful answer to Behin's question.

Begüm admitted to the confusion in the post-peer teaching interview in the following manner.

Begüm: I should better prepare for the micro level of resistance because I did not anticipate causing such confusion among the students. There was widespread confusion about it, and I contributed to it. I will address and clarify that part.

4.1.3.5 Theoretical Warrant related Challenges

In Toulmin's 1958 definition, a warrant functions as the connection between data and a claim, elucidating the reasons and processes by which the data supports the claim. In this study, a theoretical warrant relates to the connection between the dependent and independent variables established on a theoretical foundation. The participants encountered challenges in requesting the theoretical warrant, they preferred presenting it directly. Furthermore, they faced difficulties in scrutinizing the establishment of connections between the dependent and independent variables based on theoretical foundations.

4.1.3.5.1 Failure to Request Theoretical Warrant

This challenge involves the participants in the theoretical argumentation session attempting to provide theoretical warrants directly instead of questioning their students. An illustrative instance from the data analysis is offered to demonstrate this particular concern.

<u>Example</u>

Begüm's speech at the theoretical argumentation session of her peer teaching started as follows:

- Now, let us imagine you are in the shoes of an electron, attempting to navigate through a sea of atoms. It is a straightforward idea: the more difficulty you encounter, the higher the resistance you face. Difficulty equates to resistance. So, to amplify the resistance, you need to create conditions that make the electron's journey more challenging. If you increase the length, extending the path you must traverse endlessly, you will continually encounter obstacles, which means your resistance as an electron will surge. Put yourself in the electron's position. Similarly, when you reduce the cross-sectional area, and envision yourself squeezing and maneuvering through a

> narrower space; your task becomes more strenuous, and as a result, your resistance increases.
>
> Now, delving into the concept of resistivity, consider that the arrangement of atoms varies from one substance to another. In some materials, atoms are densely packed, while in others, they are more sparsely distributed. Consequently, your resistance fluctuates based on how easy or challenging your journey is. The concept of resistivity elucidates this phenomenon. If we place ourselves in the electron's perspective, we can intuitively grasp this relationship.

In this instance, Begum's consecutive participation in the entrance of the theoretical argumentation session is observed. It became evident that instead of guiding students through argumentative discussions with questions, Begum attempted to explain the secondary research question. Notably, the factors influencing the resistance of a solid conductor were explained using analogies, with a lack of theoretical data presentation. To make it sufficient, she should have elaborated on resistance at the micro level, elucidating that the resistance of substances to electric current results from the collisions between conduction electrons and intrinsic particles within the material, such as atoms. As a result, she struggled to guide students through argumentative discussions with questions and grasp the finer nuances of the physics topic at a microscopic level.

4.1.3.5.2 Failure to Prompt a Logical Connection between the Dependent and Independent Variables based on Theoretical Foundation

The challenge encompasses the participants' difficulty in questioning their students when there is a failure to establish the logical connection between the dependent and independent variables on theoretical grounds. Here is a concrete example derived from our data analysis:

<u>Example</u>

The conversation that took place between Itır, Lara, and Ece during Ece's peer teaching while Ece's students were in breakout rooms completing the conclusion parts of their activity sheets is detailed as follows.

> *Itır:* We have not conceptually understood why buoyancy increases as gravitational acceleration increases.
>
> *Ece:* Okay, not everyone has understood this. Now let us imagine that I am on Earth and I have an apple. On Earth, let us say, this apple weighs 30 N, and it floats. Since the apple is floating, what is the buoyancy force acting on it?
>
> *Itır:* It is equal to its weight.
>
> *Ece:* Certainly. If the weight were any more, the apple would have submerged; if it were any less, the apple would have ascended, even flown. Now, consider the moon; let us assume the weight of the same apple on the moon is 20 N. Consequently, the buoyant force required to achieve equilibrium will decrease proportionally. This is because buoyancy needs to equal the weight, as the net force must remain at zero.

In this instance, Ece's response to why the buoyancy force increases with an increase in gravitational acceleration is essentially a statement that must serve as a theoretical warrant and provide justification. Unfortunately, Ece's response does not provide a theoretical warrant since it lacks the theoretical data which is that the buoyant force acting on an object in a fluid is the difference in pressure forces applied to the submerged volume of the object from above and below.

The explanation about this section in Behin and İlke’s activity sheet is as follows.

- When gravity decreases, the weight of the object decreases. Since the maximum buoyant force that the liquid can apply to the object will be as much as its weight, it will also decrease.

One of the responsibilities assigned to the participants during the teaching phase was to provide feedback or pose questions when they noticed errors on their students’ activity sheets. Ece did not offer any feedback or ask questions on Behin and İlke’s statement, highlighting her struggles in interpreting the students’ reply.

4.2 Challenges Encountered by Each PPT based on Their Experience

This segment addresses the challenges encountered by each participant in their respective experiences. The examination of the data and findings is segmented into three distinct sections, each of which will be individually explored with comprehensive explanations.

4.2.1 Challenges Encountered by Begüm based on Her Experience

Begüm, in her role as a learner, encountered several challenges. These included difficulties in articulating a claim during the illumination activity, challenges in controlling variables and addressing errors in controlling variables in the shadows activity, and struggles in devising a valid investigation in the law of reflection activity. Additionally, she faced challenges in presenting a rebuttal to an invalid investigation design in the image formation at the plane mirror activity. The entirety of the challenges experienced by Begüm in her role as a learner is illustrated in Figure 4.11.

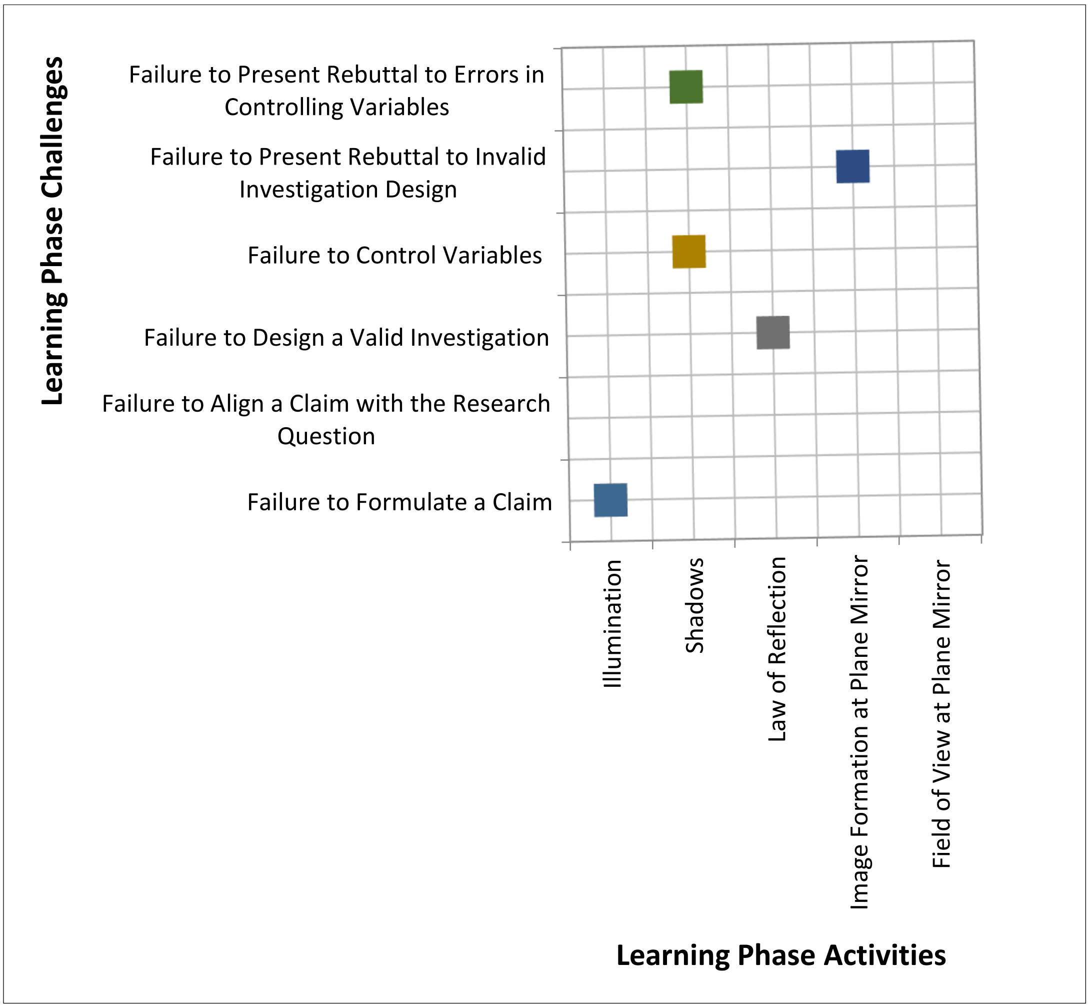


Figure 4.11. Challenges of Begüm acting as a learner in ADI activities

It is noteworthy that Begüm did not face a challenge in designing a valid investigation during the image formation at the plane mirror activity. However, she encountered a challenge in refuting her classmates' invalid investigation design during the same activity, despite the interconnected nature of these challenges suggested by their names. The distinction arises from the divergent claims participants sought to substantiate. Begüm and her groupmate devised an experiment to validate the claim that 'the image in a plane mirror is laterally symmetric to the object.' In contrast, their friends, whose experiment Begüm could not refute, posited the claim that 'the distance of the object to the plane mirror is equal to the distance of the image of the object to the plane mirror.' Consequently, the contents differed significantly in the two cases.

An essential observation is that Begüm faced varying difficulties as the activity changed, confirming the content-dependent nature of argumentation and science process skills. The alteration in the activities resulted in a shift in both the context and the content, presenting Begüm with diverse challenges associated with the relevant skills. This did not imply that skills were unteachable; certain aspects were learnable. However, when transitioning to a new activity and encountering unfamiliar elements within it, new challenges emerged.

In her role as a developer, Begüm faced just one challenge. This encompassed difficulties in comprehending the theoretical foundation underpinning the connection between the variables, which is the theoretical data in this study. The challenge experienced by Begüm in her role as a developer is depicted in Figure 4.12.

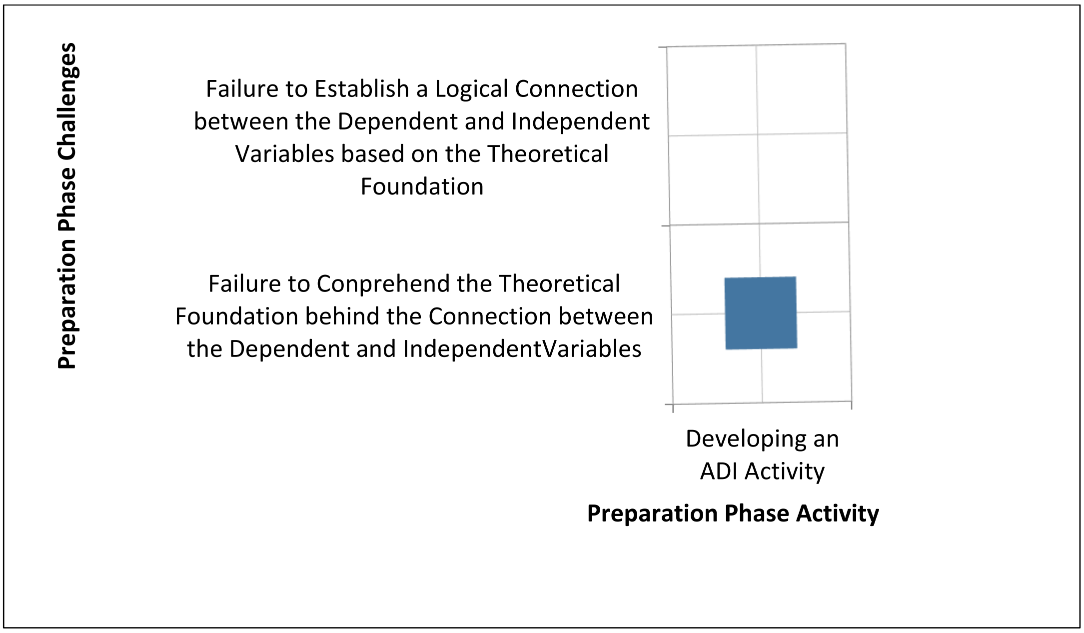


Figure 4.12. Challenges of Begüm acting as a developer in ADI activities

A notable observation emerges from Begüm's engagement in the ADI activities while assuming the role of a learner; her challenges were prominently associated with empirical data. Conversely, upon transitioning from a learner to a developer, her challenges became more salient in grappling with theoretical data.

In her capacity as a teacher, Begüm encountered numerous challenges. During her peer teaching experience, she experienced difficulties in addressing the absence of a claim, the absence of empirical data, and questioning the empirical warrant indirectly. Additionally, she faced challenges in presenting the theoretical foundation supporting the connection between variables and requesting the theoretical warrant.

In her high school teaching experiences, Begüm successfully addressed the difficulties associated with questioning the lack of a claim and requesting the theoretical warrant. However, she continued to face difficulties in questioning the empirical data, questioning the empirical warrant with an unnecessary leading, and presenting the theoretical data insufficiently. The comprehensive array of challenges Begüm encountered in her role as a teacher is delineated in Figure 4.13.

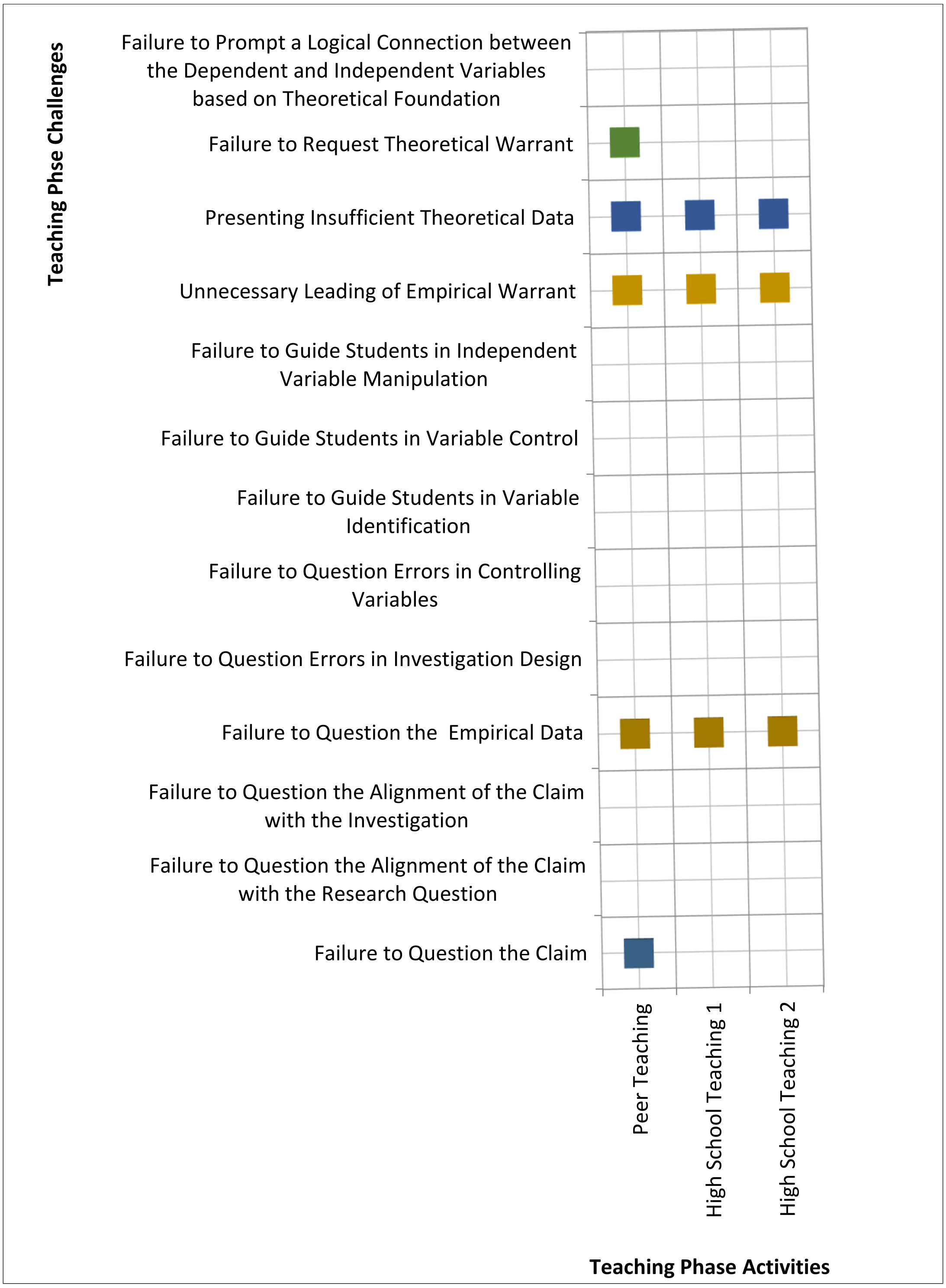


Figure 4.13. Challenges of Begüm acting as a teacher in ADI activities

It is crucial to underscore that the absence of instances related to failure to question errors in investigation design, failure to question errors in controlling variables, and failure to guide students in variable identification, variable control, and independent variable manipulation in Figure 4.13 does not imply that Begüm did not encounter these challenges. Instead, it indicates that circumstances conducive to experiencing these challenges did not arise. To confront challenges such as failure to question errors in investigation design or controlling variables, Begüm would have first needed to overcome the initial difficulty of failure to question the empirical data. Similarly, the absence of instances related to failure to prompt a logical connection between the dependent and independent variables based on theoretical foundations does not suggest that Begüm did not face this challenge. Confronting this challenge would necessitate addressing the antecedent challenge of failure to present the theoretical data.

Upon scrutinizing Figures 4.11, 4.12, and 4.13 collectively, a clear pattern emerges. When Begüm assumed the role of a learner in ADI activities, she encountered no challenges related to the theoretical data and the theoretical warrant. However, in her role as a teacher in the ADI activities, challenges surfaced in effectively presenting these insights within the ADI materials and probing them during her teaching experiences.

4.2.2 Challenges Encountered by Banu based on Her Experience

In her learner role, Banu faced challenges with aligning claims (shadows), controlling variables (shadows, image formation at the plane mirror, field of view at a plane mirror), presenting rebuttals to errors in controlling variables (shadows), and formulating valid investigations (law of reflection, image formation at the plane mirror). The challenges are depicted in Figure 4.14.

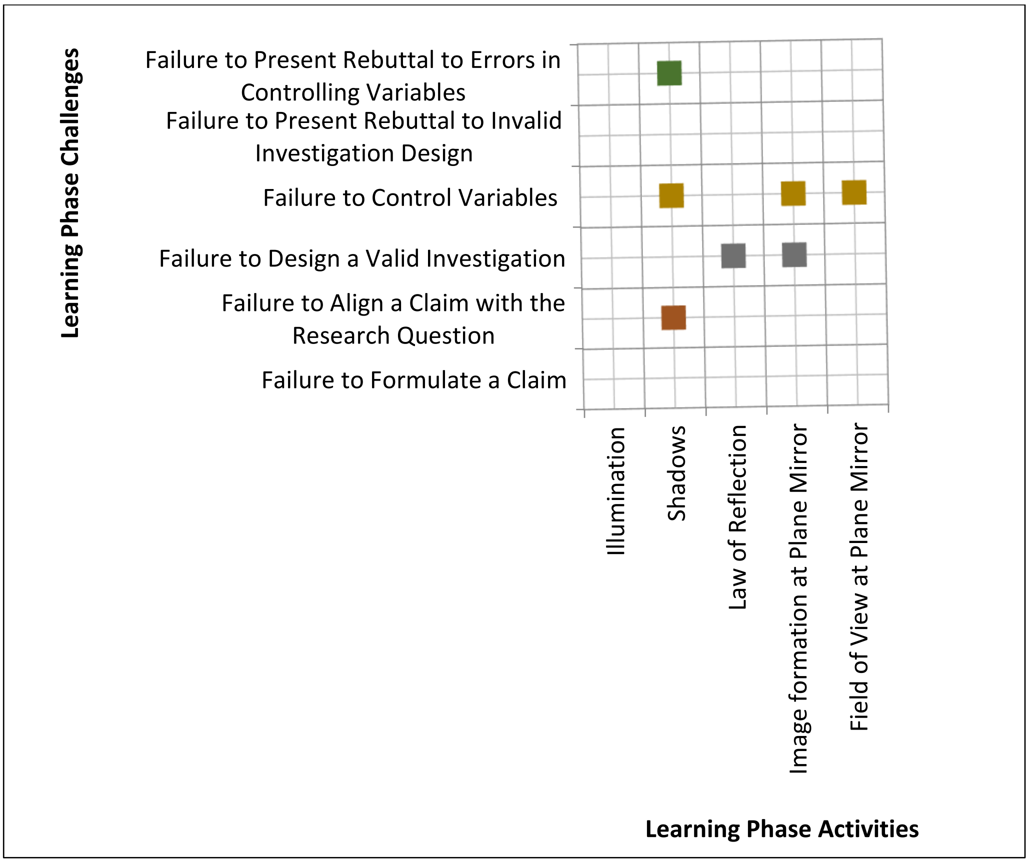


Figure 4.14. Challenges of Banu acting as a learner in ADI activities

Significantly, Banu encountered a challenge in obtaining valid data as a result of facing difficulties in devising a valid investigation and controlling variables during the learning phase.

In her role as a developer, Banu did not encounter any related challenges. However, in her role as a teacher, Banu faced several difficulties. During her peer teaching experience, she struggled with questioning the alignment of a claim with the research question, probing the empirical data, addressing errors in investigation design, addressing errors in controlling variables, guiding students in independent variable manipulation, and prompting a logical connection between the dependent and independent variables based on theoretical data. In her first high school experience, her only setback was in questioning errors in controlling variables and overcoming other challenges. In her second high school experience, she successfully overcame her difficulty in questioning errors in controlling variables. The comprehensive array of challenges Banu encountered in her role as a teacher is delineated in Figure 4.15.

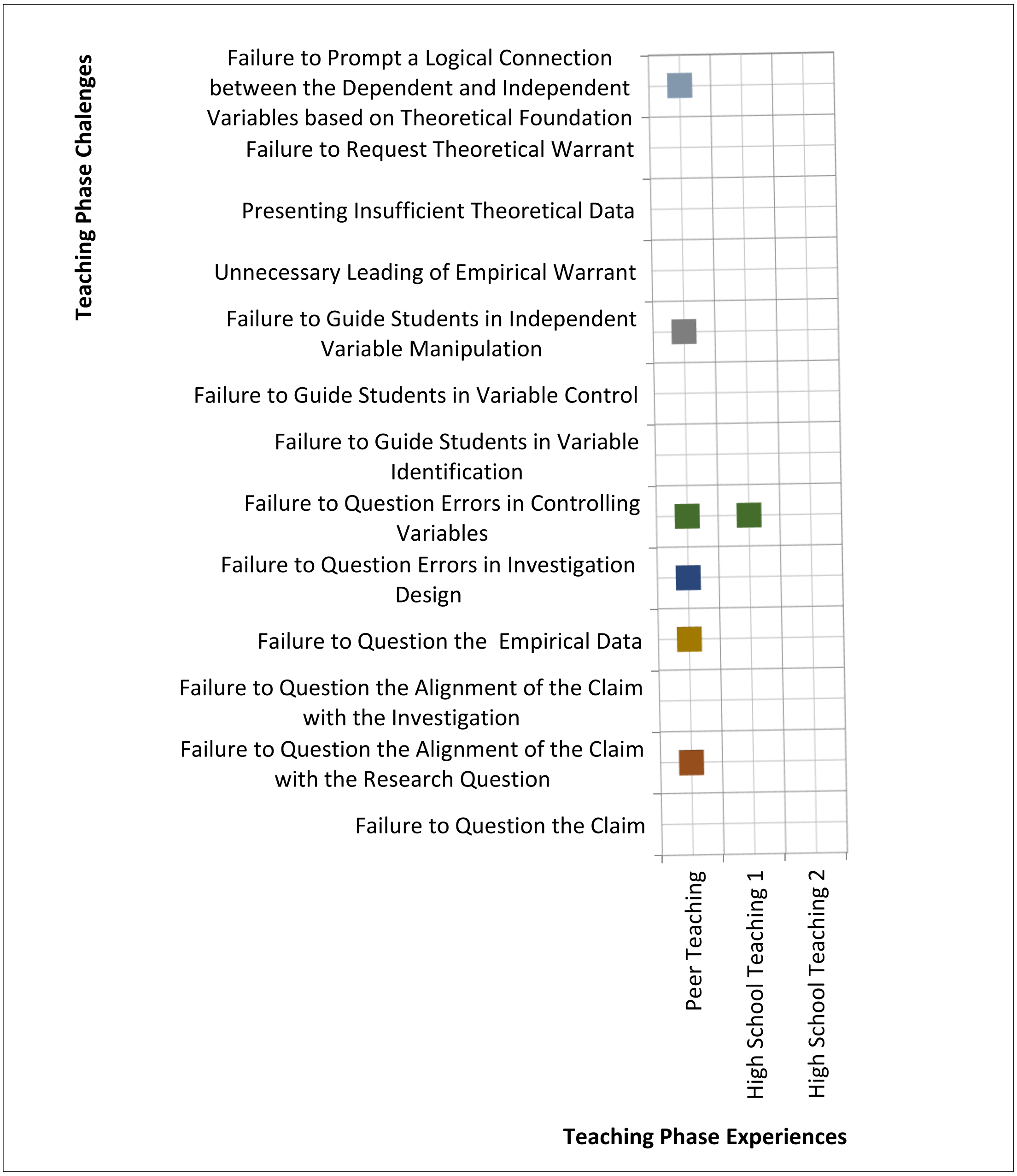


Figure 4.15. Challenges of Banu acting as a teacher in ADI activities

Upon analyzing Figures 4.14 and 4.15, a notable distinction emerges. Banu encountered a challenge in the teaching phase that was absent during the learning phase. In her learning phase, Banu did not face any difficulty in manipulating the independent variable. In her teaching experience, Banu selected torque as the focus, and while she faced no challenges with length and force, two factors influencing torque, she struggled with manipulating the angle. Banu did not consistently face challenges in identifying variables, particularly in subjects concerning angles, as illustrated by these instances.

4.2.3 Challenges Encountered by Ece based on Her Experience

In her learner role, Ece faced various challenges, including struggles in devising a valid investigation and failing to counter invalid investigation design in the illumination activity. She also encountered difficulties in aligning a claim with the research question and presenting a rebuttal to errors in controlling variables in the shadows activity. Importantly, Ece overcame her challenges and did not encounter challenges in the law of reflection activity, image formation at the plane mirror activity, and field of view at a plane mirror activity. A comprehensive overview of the challenges experienced by Ece in her learner role is depicted in Figure 4.16.

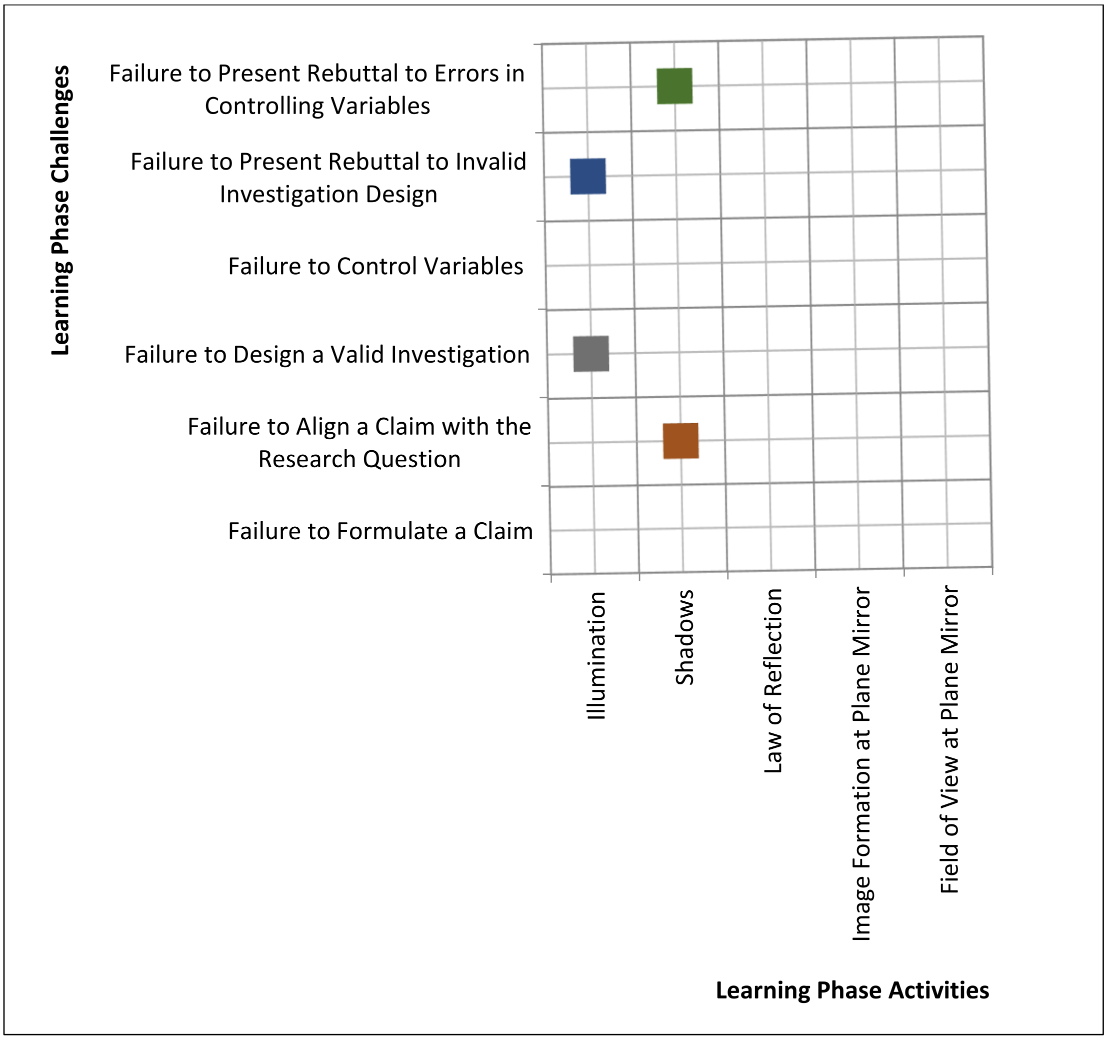


Figure 4.16. Challenges of Ece acting as a learner in ADI activities

It is notable that Ece did not encounter challenges in controlling variables during the shadows activity. However, she did face a challenge in refuting errors made by her classmates in controlling variables in the same activity, despite the interconnected nature implied by the names of these challenges. Both Ece's group and another group in the class conducted experiments to validate the same claim: 'As the distance of a point light source from an obstacle increases, the size of the umbra on the screen situated behind the obstacle decreases.'. The discrepancy arises from the differing approaches the groups took in their investigations. While Ece's group altered the position of the point source, the other group changed the position of the obstacle.

Although the other group incorrectly replicated the same experiment as Ece and her groupmate, Ece did not recognize the error in the incorrect experiment and, consequently, could not offer a rebuttal. In essence, even when the data collection processes are similar, the absence of challenges with controlling variables for one individual does not guarantee an ability to notice issues with the controlling variables used by others.

A crucial observation is that, akin to Begüm, Ece confronted different challenges as the activity changed. The shift in activity led to a change in both the context and the content, exposing Ece to a spectrum of challenges related to argumentation and science process skills.

As a developer, Ece encountered a solitary challenge, which involved struggles in establishing a logical connection between the dependent and independent variables based on a theoretical foundation, specifically the theoretical warrant in this study. The challenge experienced by Ece in her developer role is illustrated in Figure 4.17.

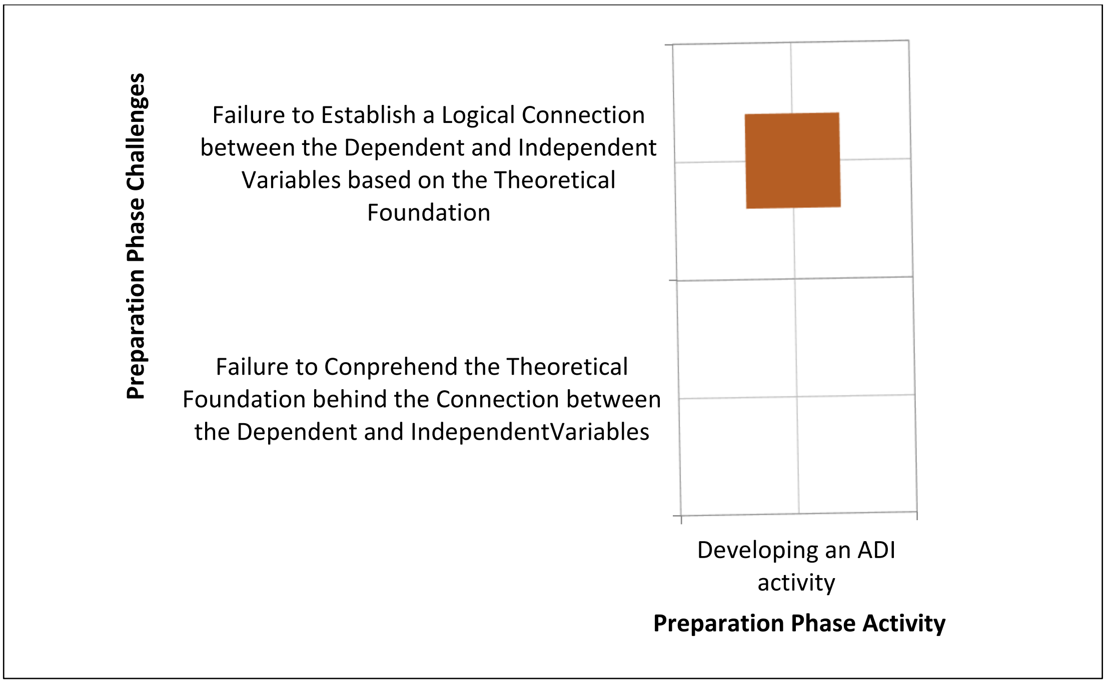


Figure 4.17. Challenges of Ece acting as a developer in ADI activities

A significant observation arises from Ece's engagement in the ADI activities: while assuming the learner role, she encountered no challenges in the theoretical argumentation session. Conversely, upon transitioning from the learner role to the developer role, the challenges she faced in establishing a logical connection between the variables based on the theoretical foundation, specifically the theoretical warrant, became more evident.

In her role as a teacher, Ece faced several challenges. During her peer teaching experience, she encountered difficulties in scrutinizing the alignment of claims with the investigation, addressing the empirical data, and guiding students in variable identification and control. Additionally, she struggled with requesting theoretical warrants and questioning the connection between the dependent and independent variables based on theoretical foundations.

In her high school teaching experiences, Ece did not face challenges pertaining to questioning the alignment of claims with the investigation, addressing the empirical data, guiding students in variable control, and requesting theoretical warrants. However, she persisted in encountering challenges related to guiding students in variable identification and questioning the connection between the dependent and independent variables based on theoretical foundations. The complete set of challenges Ece experienced in her teacher role is outlined in Figure 4.18.

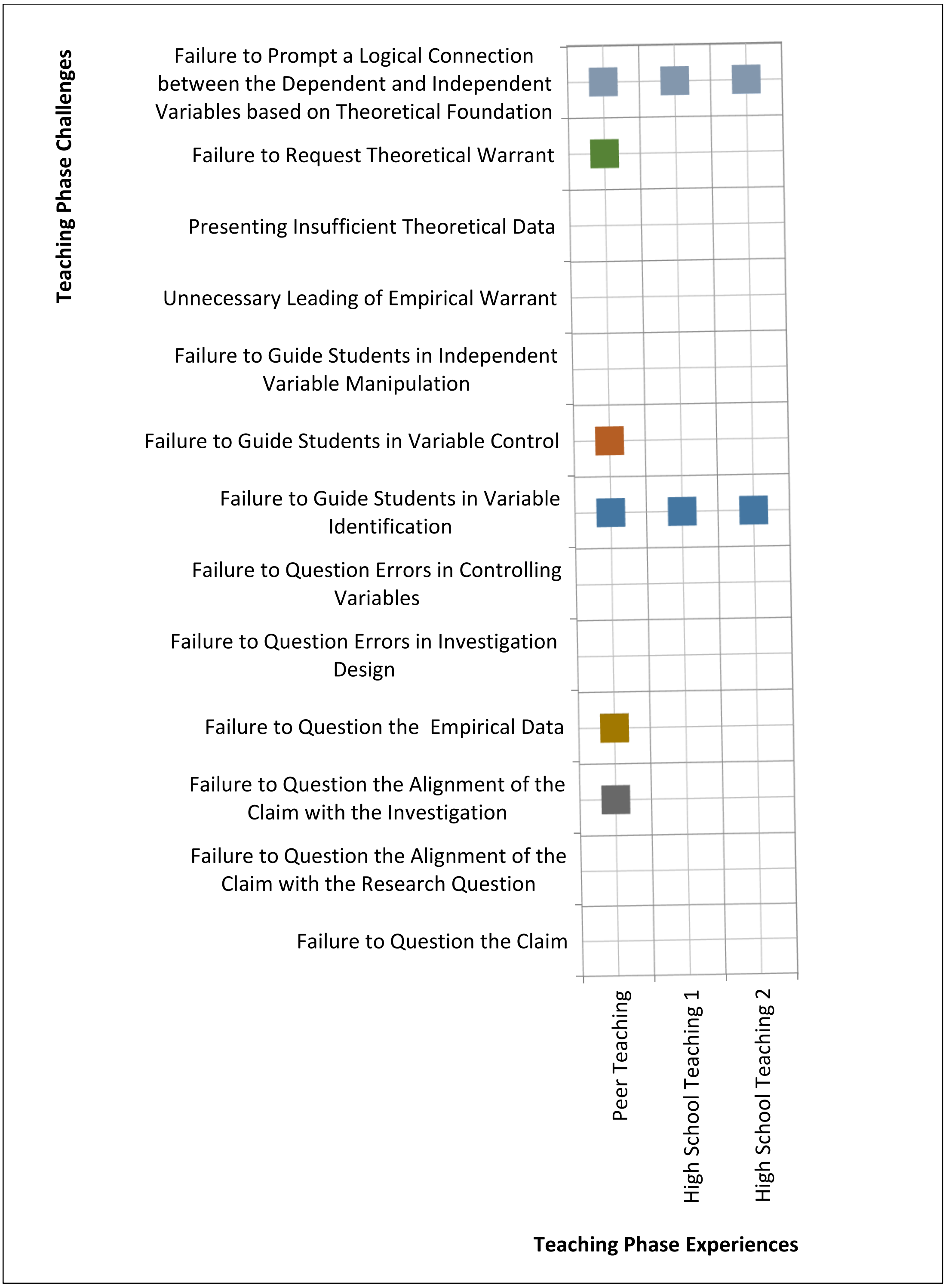


Figure 4.18. Challenges of Ece acting as a teacher in ADI activities

It is essential to emphasize that Ece's challenge in guiding students in variable identification is not uniform across all student claims. Ece encountered this challenge specifically in the following two claims when her students used a floating object:

1. If the density of an object in a fluid increases (decreases), the buoyancy force acting on the object increases (decreases).

2. If the density of the fluid increases (decreases), the buoyancy force acting on the object in the fluid increases (decreases).

During student investigations involving a floating object, they observed that increasing the density of the object led to an increase in its submerged volume, and increasing the density of the fluid resulted in a decrease in the submerged volume, consistent with expectations. Unfortunately, Ece perceived this scenario as involving the simultaneous alteration of two variables, as detailed in the explanation under the failure to guide students due to difficulty in variable identification. In these examples, the submerged volume is a dependent variable; however, Ece perceived it as a controlled variable.

Upon examining Figures 4.16, 4.17, and 4.18 collectively, a distinct pattern becomes evident. Ece faced no challenges related to variable identification when adopting the roles of a learner and a developer in the ADI activities. However, challenges arose when she assumed the role of a teacher. As previously explained, Ece conducted teaching experiences using the material prepared during the preparation phase. Even though the material remained consistent, there was a shift in Ece's role, resulting in a novel challenge.

Another notable insight emerges from Ece's participation in the ADI activities: when taking on the role of a learner, she faced no difficulties during the theoretical argumentation session. However, as she shifted from the learner role to the developer role and subsequently to the teacher role, the difficulties in prompting a logical connection between the variables based on the theoretical foundation, particularly the theoretical warrant, became more apparent.

CHAPTER 5

DISCUSSION, IMPLICATIONS, AND RECOMMENDATIONS FOR FURTHER STUDIES

This chapter is divided into three parts. The initial section covers the discussion of the findings. The second section delves into the potential implications of the results for educators' practices. Finally, the third section offers recommendations for future studies.

5.1 Discussion of the Findings

The objective of this study was to explore the challenges encountered by pre-service physics teachers (PPTs) in various roles: as learners in ADI activities, as integrators of ADI into the Turkish physics curriculum, and as instructors implementing ADI activities. In pursuit of this objective, revisions were made to argument-driven inquiry (ADI) method, prompted by the recognition of disparities between its theoretical framework and practical implementation during the inquiry phase (see Grooms et al., 2016; Walker et al., 2011). Subsequently, the researcher undertook a redesign of the MSE 407 Laboratory Applications of Secondary Science Education II course during the spring semester of the 2020-2021 academic year. This elective course, offered by the Mathematics and Science Education Department at Middle East Technical University, involved four hours of weekly instruction. The course was structured into three phases: the learning phase, the preparation phase, and the teaching phase. The challenges faced by the three lowest-achieving students in all phases were scrutinized to enhance our comprehension of the challenges encountered by the PPTs.

The study encountered a variety of challenges for the PPTs, with each difficulty leading to another. Upon reviewing the gathered data, it became apparent that the PPTs struggled with different skills, including argumentation, science process, and grasping essential concepts. The analysis indicated that difficulties in science process, and conceptual understanding have served as antecedents to challenges in argumentation. As a result, this research emphasizes presenting findings specifically related to challenges in argumentation skills. Accordingly, Toulmin's (1958) structural model, Toulmin Argument Pattern (TAP), was employed to identify challenges related to argumentation skills. TAP comprises six components: Claim, data, warrant, backing, qualifier, and rebuttal. The study incorporates both empirical and theoretical argumentation sessions, with the inclusion of the terms "empirical" and "theoretical" to precisely identify the nature of the argumentation session in which a challenge emerges.

In this regard, the findings, along with the discussions, are elucidated as follows:

Finding 1: The PPTs faced challenges with the argumentation skills of formulating and presenting claims, empirical data, and empirical rebuttals while acting as learners in the ADI activities.

In the context of the ADI, the process of claim formulation takes on a pivotal role, serving as a bridge between participants' past experiences and their attempts to address the primary research question. The claim, akin to a hypothesis in inquiry research settings, becomes a focal point of exploration. This study unveils a nuanced landscape where participants grapple with the intricate task of crafting claims that not only draw from their experiences but also align closely with the overarching research questions. The challenges encountered in this phase are multifaceted, with instances where participants refrained from aligning the claims with the primary research questions or formulating claims altogether, reflecting the complexities inherent in this cognitive process. This departure from conventional practices sheds light on the distinctive nature of claim formulation within the ADI framework.

Comparing the findings of the current study with earlier investigations in both argumentation and science process skills literature, intriguing disparities surface. While existing studies often underscore the challenge of modifying claims (Berland & Reiser, 2011; Kaçar & Balım, 2021; Novak & Treagust, 2017; Walker et al., 2019), even when faced with refuting evidence, this study introduces a novel dimension by emphasizing the initial formulation of claims. This shift in focus is particularly relevant in the ADI setting, where the integration of inquiry adds layers of complexity to the entire process. The authenticity of the inquiry process in this study exposed the claim (hypothesis) derived from prior experiences, allowing us to recognize the inherent challenges encountered by the participants. Notably, the exploration into hypothesis formation challenges aligns with existing literature, albeit limited in the domain of undergraduate students. Kaçar and Balım's (2021) study on science learning through ADI among middle school students resonates with the findings of this study, revealing difficulties in determining research questions and formulating hypotheses. The extension of these challenges to the undergraduate level, as evidenced in this study, underscores the need for tailored pedagogical approaches that address the intricacies of hypothesis formation within the ADI framework.

The challenges participants faced in collecting empirical data reveal a crucial aspect of the limitations within the setting of the ADI. The difficulty in controlling variables and devising a valid experiment, leading to compromised data presentation during empirical argumentation sessions, underscores a specific hurdle in the ADI approach. Interestingly, while these challenges are distinctly categorized in the literature as empirical data-related issues, the absence of studies differentiating between empirical and theoretical data challenges within the ADI is notable. This gap in the literature points towards an opportunity for future research to delve into the nuanced intricacies of data-related challenges specific to ADI.

Comparing the ADI to existing literature on argumentation and inquiry, it becomes evident that challenges related to argumentation skills and scientific process skills have been extensively explored across educational levels. The alignment of the findings of this study with existing literature highlights consistency in the struggles encountered by students in different educational settings. When considering challenges related to science process skills, our study aligns with existing literature focused on middle school students. The difficulties in designing a valid experiment, controlling variables, and various aspects of inquiry learning identified in this study find resonance in the challenges faced by students at the middle school level, as reported by Castro and Morales (2017), Duggan et al. (1996), Kaçar and Balım (2021), and Krajcik et al. (1998). This alignment emphasizes that challenges in the ADI are not unique but share commonalities with broader educational settings, potentially contributing to a more comprehensive understanding of the challenges associated with scientific learning.

Moreover, the findings of the study align with existing literature that highlights challenges in argumentation skills, particularly regarding the use of evidence. Kelly and Chen (1999), Sandoval (2003), and Sandoval and Millwood (2005) independently observed that high school students frequently formulate arguments with limited or no utilization of evidence. This consistent observation across multiple studies emphasizes a pervasive challenge in argumentation skills, resonating with the identification of similar issues within the ADI context.

Examining argument patterns in prior research by Jiménez-Aleixandre et al. (2000), and Sadler (2004) further underscores the significance of the findings of this study. Sadler emphasizes the challenges faced by high school students engaged in argumentation activities, noting varying levels of argument quality, ranging from naive to sophisticated. The identification of naive arguments, characterized by claims made without supporting data, aligns with the observations in the ADI framework. This alignment strengthens the argument that challenges in argumentation skills, particularly the use of evidence, are not unique to the ADI but are part of broader issues observed in diverse educational settings. The integration of these findings into the broader literature on argumentation contributes to a more comprehensive understanding of the challenges students face in developing effective argumentation skills.

The challenges participants faced in noticing invalid data and subsequent difficulties in presenting empirical rebuttals highlight a critical aspect of the limitations within the ADI framework. The issues stem from flawed investigation designs or errors in controlling variables, leading to the collection of invalid data. These challenges necessitate an empirical rebuttal, but the participants encountered further obstacles in recognizing and addressing the invalidity of the data.

Interestingly, the literature lacks explicit categorization of challenges related to rebuttals as either empirical or theoretical, specifically addressing the struggles of undergraduate students in managing rebuttals. However, existing studies focusing on challenges across different educational levels provide insights into the broader educational settings.

The findings of this study align with existing literature on ADI challenges. Kaçar and Balım's (2021) exploration of science learning through ADI among middle school students revealed difficulties not only in constructing counterarguments and rebuttals but also in evaluating peers' arguments. This resonates with the observations of challenges faced by undergraduate students in presenting empirical rebuttals within the ADI framework.

Additionally, Aydeniz and Ozdilek (2016) delved into the challenges encountered by students of PPTs during an argument-based implementation, identifying difficulties in utilizing rebuttals. Sadler's (2004) emphasis on challenges faced by students learning science through argumentation activities, drawing on the argument patterns identified by Kortland (1996) and Jiménez-Aleixandre et al. (2000), further supports our findings. Sadler noted that middle school students in Kortland's study often provided direct support for their claims without incorporating counterclaims or rebuttals, reflecting similarities with challenges observed in our study.

Furthermore, Sadler highlighted the varying levels of argument quality among high school students in the Jiménez-Aleixandre et al. study, ranging from naive to sophisticated, with sophisticated arguments sometimes lacking rebuttals. This alignment with the observations of this study emphasizes that challenges in managing rebuttals, even at the undergraduate level, echo broader issues observed across different educational levels.

On the other hand, this study reveals a gap in the existing literature concerning challenges related to the noticing of invalid investigation designs and errors in controlling variables. While challenges related to rebuttals have been explored to some extent, the specific difficulties in recognizing flawed designs and errors in controlling variables within the ADI context remain unaddressed in the current scholarly discourse. This points to a unique contribution of our study, shedding light on an aspect that has been overlooked in the broader literature on argumentation and inquiry.

While this study did not explicitly focus on challenges related to warrants, the broader literature reveals significant issues in this domain, particularly in the sphere of science learning through argumentation. Lazarou et al. (2016) highlighted challenges among primary school students, noting that their arguments were often insufficient, limited, and simplistic. The root cause of this inadequacy lay in their struggles to support claims with reasons, and even when attempts were made, the provided reasons were frequently deemed inadequate.

Extending this observation to high school students, various studies, including Lizotte et al. (2003), Kelly et al. (1998), Abi-El-Mona and Abd-El-Khalick (2006), McNeill (2009), Aydeniz and Ozdilek (2016), and Sadler (2004), collectively underscored the challenges encountered in constructing arguments without proper warrants. These studies collectively reveal a persistent struggle among high school students to effectively support their claims with well-reasoned justifications.

Turning to the specific sphere of ADI, Sampson and Walker (2012) delved into challenges faced by undergraduate students using this approach. Their findings highlighted difficulties in providing adequate background information, explaining the purpose of data collection and experimental design, justifying claims with laws and theories, and appropriately using science-specific terminology. This aligns with the broader literature on warrants, emphasizing that challenges in this area persist even at the undergraduate level, with ADI not immune to these difficulties.

Similarly, Walker et al. (2019) explored undergraduate students' struggles in argumentation sessions designed with ADI, revealing specific challenges in justifying claims with laws and theories and using evidence without proper warranting. This observation supports the notion that ADI while providing a unique framework for science learning, does not eliminate the broader challenges associated with warrants in argumentation.

Furthermore, Zembal-Saul et al. (2002) found that PPTs faced challenges in constructing complex forms of arguments, such as justification, beyond mere evidence presentation. This aligns with the challenges observed in ADI and reinforces the idea that while ADI may enhance certain aspects of argumentation, challenges related to warrants persist and are not entirely addressed by this approach.

Finding 2: The PPTs faced challenges with the argumentation skills of constructing theoretical data and theoretical warrant while integrating ADI into the Turkish physics curriculum.

Within the realm of theoretical data challenges identified in this study, participants grappled with the difficulty in grasping the theoretical foundation that underpins the connection between variables – constituting theoretical data. This nuanced challenge extends further to the formulation of the theoretical warrant, a critical aspect denoting the link between the dependent and independent variables grounded in a theoretical foundation.

Interestingly, the term "theoretical warrant" encapsulates the crux of this challenge, highlighting the need for participants not only to understand the theoretical data itself but also to articulate a coherent and well-justified connection between variables based on that data. The intricacies involved in this process shed light on the depth of challenges inherent in the theoretical aspect of the ADI.

Comparing these findings to the broader literature, a noticeable dearth of studies specifically addressing challenges in lesson preparation related to inquiry, argumentation, or ADI in this specific context is apparent. The scarcity of literature addressing the intricacies of formulating theoretical warrants, as observed in this study, points to an underexplored facet in the existing discourse on science education.

However, Sampson and Blanchard's (2012) exploration of why secondary science teachers refrained from incorporating argumentation into their classrooms offers a valuable point of alignment with the findings of this study. Their study, akin to this study, emphasized the challenges faced by teachers in presenting data and reasoning. While not directly addressing the formulation of theoretical warrants, Sampson and Blanchard's work highlights a parallel struggle in the broader spectrum of incorporating argumentation in science education, underscoring the intricate nature of presenting data and reasoning, a theme resonant with this study's focus on theoretical data challenges.

This alignment with Sampson and Blanchard's work contributes to a broader understanding of challenges in science education, emphasizing that the difficulties observed in this study are not isolated but share commonalities with challenges faced by educators in various instructional settings. The theoretical data-related challenges identified in this study, when viewed in light of the existing literature, underscore the need for a more comprehensive exploration of the theoretical dimensions within the ADI framework and its implications for effective science learning. This presents an avenue for future research to delve deeper into the intricacies of theoretical data challenges within the ADI and their implications for instructional practices.

Finding 3: The PPTs faced challenges with the claims, empirical data, theoretical data, empirical warrants, and theoretical warrants while acting as teachers in the ADI activities.

The challenges encountered by the PPTs within the ADI offer a nuanced understanding of the complexities involved in guiding students through the scientific reasoning process. Delving into these challenges unveils specific dimensions related to claims, empirical data, theoretical data, empirical warrant, and theoretical warrant.

In terms of claims, the PPTs grappled with multifaceted challenges, including the failure to question the claim, assess alignment with the research question, and evaluate alignment with the investigation. These challenges underscore the intricate nature of guiding students in constructing meaningful claims within the ADI framework. Surprisingly, the literature lacks specific studies delving into claim-related challenges in ADI, argument-based or inquiry-based approaches. This gap highlights the unique contribution of this study in shedding light on an underexplored aspect of science pedagogy.

Empirical data challenges for the PPTs within the ADI extend beyond conventional issues such as overlooking errors in investigation designs and controlling variables. One distinctive challenge identified is the neglect to question the empirical data, signifying a need for targeted support in data collection methodologies within the ADI framework. This challenge underscores the unique intricacies associated with empirical data collection in the ADI, necessitating specialized guidance to enhance PPTs' competence in this aspect.

The struggles faced by the PPTs in guiding students, arising from their difficulties in identifying variables, controlling variables, and manipulating independent variables, present a notable point of departure from challenges commonly identified in the literature. This misalignment emphasizes the necessity for targeted support structures tailored explicitly to the ADI's distinctive features. While existing literature acknowledges challenges in guiding students through inquiry-based teaching (Yoon et al., 2012), the specific nuances related to variable manipulation within the ADI suggest a need for a more tailored approach to teacher professional development and training.

In the broader context of inquiry-based teaching, Yoon et al. (2012) explored challenges faced by pre-service elementary teachers and identified difficulties in guiding students to conduct valid experiments and support data analysis due to insufficient science and pedagogy content knowledge. The alignment of these findings with the results of the present study further emphasizes the universality of challenges faced by educators when implementing inquiry-based approaches across different educational levels.

Theoretical data challenges reveal a gap in preparing teachers to present the theoretical foundation underlying the connection between variables effectively. This stands as a unique challenge within the ADI, with limited comparative studies in the literature. The findings align with Sampson and Blanchard's exploration of teachers refraining from incorporating argumentation, emphasizing challenges in presenting data and reasoning (Sampson & Blanchard, 2012).

Empirical and theoretical warrant-related challenges for the PPTs highlight the need for a nuanced understanding of warrant issues within the ADI. The unnecessary leading of empirical warrant, the failure to request the theoretical warrant, and the failure to inquire about the establishment of the connection between the variables based on the theoretical foundation underscore the intricacies involved in guiding students through justifying claims.

The absence of notice regarding students' argumentation and science process skills points to an overarching challenge in teacher awareness and guidance. This adds a layer of complexity to the discussion, emphasizing the need for professional development focusing on honing teachers' observational skills. While not categorized into empirical and theoretical groups and not examined in the same depth as in this study, there are two studies in the literature that closely align with these findings. One study was identified focusing on challenges related to guidance through questioning data and warrant. Additionally, only one study was found exploring the reasons why argumentation-based pedagogy was not favored in classrooms. The findings of this study align with existing literature. Aydeniz and Özdilek (2016) examined the challenges encountered by PPTs during argument-based science learning. The study revealed that PPTs faced difficulties in guiding students in constructing arguments and assessing their arguments, particularly concerning evidence and reasoning. Newton et al. (1999) conducted interviews with 14 experienced science teachers to investigate the reasons why argumentation-based pedagogy was not preferred in their classrooms. The study highlighted that limited pedagogical knowledge, skills, and epistemological understanding among science teachers were significant factors, contributing to a lack of confidence and guidance in facilitating discussions.

Finding 4: The challenges faced by each PPT vary for each phase and each activity.

<u>Begüm's Journey</u>

Begüm, a 23-year-old sophomore female student, was pursuing a Physics Education degree in the Department of Mathematics and Science Education. She had successfully completed about half of the physics courses offered by the Department of Physics. Additionally, during the same semester as the MSE 407 course, she had taken high school physics curriculum review I and curriculum development and instruction. It is worth noting that at the time of this study, she had not yet taken courses in methods of science teaching in secondary education I, methods of science teaching in secondary education II, high school physics curriculum review II, laboratory applications in secondary science education I, school experience, or practice teaching.

In her role as a learner, Begüm encountered a diverse set of challenges that contributed to her overall educational journey. These challenges included difficulties in articulating a clear claim during the illumination activity, navigating complexities in controlling variables and presenting a rebuttal to the peers' errors regarding variable control in the shadows activity, facing challenges in formulating a valid investigation in the law of reflection activity, and countering an invalid investigation design in the image formation at the plane mirror activity. The transition between activities brought about a change in both context and content, leading Begüm to confront various challenges related to essential skills. It is crucial to note that facing different challenges in each activity does not necessarily imply a lack of skill acquisition.

To assess skill development, pre-tests and post-tests were administered to the PPTs before and after the learning phase. The science process skills test by Burns et al. (1985) served as one of the assessment tools. Begüm's scores on the scientific process skills test improved from 17 in the pre-test out of 24 to 23 in the post-test out of 24. In the pre-test, she struggled with hypothesis formulation and variable identification questions, but in the post-test, mistakes were limited to a single variable identification question. While the test results indicate an improvement in skills, engaging in new activities, encountering different content, and facing diverse contexts may introduce unique challenges.

It is worth highlighting that during the fall semester of 2020-2021, Begüm concurrently took the optics and waves course resulting in an FD grade. However, she excelled in the MSE 407 course with an AA grade. Initially unfamiliar with the content of each activity, Begüm acquired optics concepts through the study, presenting a potential challenge.

In her role as a developer, Begüm faced challenges in grasping the theoretical underpinnings that form the basis for the relationship between variables, particularly in the context of theoretical data within this study. Prior to MSE 407, Begüm completed an introductory electricity course with a moderate grade of CB. This course covered the subject matter she chose for her ADI activity, "Factors affecting the resistance of a solid conductor," but approached it from a macro perspective. Transitioning to her ADI activity, she had to delve into the micro-level considerations, addressing the factors influencing the resistance of a solid conductor as the theoretical data. Given that this represented her initial foray into macro-micro teaching, encountering such a challenge was expected.

As a teacher, Begüm faced a multitude of challenges. While engaged in peer teaching, she grappled with addressing the claim, the empirical data, and the indirect questioning of the empirical warrant. Moreover, she encountered difficulties in presenting the theoretical foundation that underpins the connection between variables, requesting the theoretical warrant. During her high school teaching experiences, Begüm did not face challenges related to querying the claim and requesting the theoretical warrant. Nevertheless, she persisted in grappling with difficulties in questioning the empirical data, unnecessary leading of empirical warrant, and presenting the theoretical foundation supporting the connection between variables.

It is crucial to emphasize that the absence of instances related to challenges like failing to question errors in investigation design, controlling variables, and guiding students in variable identification, control, and manipulation does not imply Begüm did not encounter these challenges. Instead, it indicates that circumstances conducive to experiencing these challenges did not arise. To tackle challenges like failing to question errors in investigation design or controlling variables, Begüm would have first needed to overcome the initial difficulty of failing to question empirical data.

Similarly, the absence of instances related to failing to prompt a logical connection between dependent and independent variables based on theoretical foundations does not suggest Begüm did not face this challenge. Addressing this challenge would require first overcoming the antecedent challenge of failing to present theoretical data.

Upon thorough analysis of Begüm's roles as a learner, developer, and teacher, a notable pattern comes to light. When taking on the role of a learner in ADI activities, Begüm encountered no challenges related to theoretical data and the theoretical warrant. However, when assuming the role of a teacher in the ADI, she faced difficulties in articulating these insights effectively within the ADI materials and probing them during her teaching experiences. This phenomenon may be attributed not only to Begüm's shift in roles but also to the novelty of her engagement with the specific subject she is addressing at a micro level for the first time.

Banu’s Journey

Banu, a 23-year-old junior female student, was pursuing a degree in Physics Education within the Department of Mathematics and Science Education. Having successfully completed about half of the physics courses offered by the Department of Physics, she was concurrently enrolled in methods of science teaching in secondary education I and laboratory applications in secondary science education I during the same semester as the MSE 407 course. Before the initiation of this study, she had finished courses in high school physics curriculum review I, and curriculum development and instruction. Notably, at the time of this study, she was not currently taking courses in methods of science teaching in secondary education II, high school physics curriculum review II, school experience, or practice teaching.

Banu's role as a learner in the ADI activities revealed challenges in aligning claims, controlling variables, presenting rebuttals, and devising valid investigations across various tasks such as shadows, law of reflection, image formation at the plane mirror, and field of view at a plane mirror. Despite an improvement in scientific process skills, reflected in her test scores rising from 19 to a perfect 24, Banu encountered persistent challenges when introduced to new content in subsequent ADI activities.

Of particular interest is Banu's perfect score in the science process skill post-test, suggesting optimal development in these skills. However, the recurrence of challenges in designing valid investigations and controlling variables underscores the nuanced nature of skill transfer. While the test questions provided a comprehensive examination of the experimentation process, the active participation and discovery process in the ADI activities introduced potential variations in challenge manifestation.

Additionally, Banu's completion of the optics and waves course before MSE 407, despite an average CC grade, highlighted her initial unfamiliarity with the content of each ADI activity. Her subsequent excellence in the MSE 407 course, securing an AA grade, demonstrated a significant learning curve.

In her role as a developer, Banu navigated through her responsibilities without encountering any discernible challenges. However, the transition to the role of a teacher brought forth a set of complexities. During her peer teaching experience, she grappled with a spectrum of challenges, including questioning claim alignment, probing empirical data, addressing errors in investigation design, managing errors in controlling variables, guiding students due to her struggles in manipulating the independent variable, and scrutinizing the connection between dependent and independent variables based on theoretical data.

Banu's initial high school teaching experience presented a singular setback, primarily revolving around questioning errors in controlling variables, as she successfully overcame other challenges. Remarkably, in her subsequent high school teaching experience, she triumphed over her earlier difficulty in questioning errors related to controlling variables.

An intriguing observation is the emergence of a challenge in the teaching phase that was absent during the learning phase. While Banu faced no issues in manipulating the independent variable in her learning phase, a different scenario unfolded in her teaching experience. Choosing torque as the focal point, Banu navigated effortlessly through length and force, the two factors influencing torque, but encountered difficulties with manipulating the angle.

Independent variable manipulation did not consistently pose challenges for Banu, particularly in topics related to angles. This is evident in her learning phase, where she struggled with angle measurement in the laws of reflection activity. The recurrence of a similar problem suggests that Banu's challenge in independent variable manipulation might be rooted in the concept of angles. This nuanced exploration delves into the multifaceted nature of challenges encountered by Banu in her various roles and phases within the ADI framework.

Ece's Journey

Ece, a 23-year-old junior female student, was pursuing a Physics Education major within the Department of Mathematics and Science Education. She had completed approximately half of the physics courses offered by the Department of Physics. In the same semester as the MSE 407 course, Ece was concurrently enrolled in curriculum development and instruction, along with high school physics curriculum review I. It is worth noting that she was not currently registered for courses in methods of science teaching in secondary education I, methods of science teaching in secondary education II, high school physics curriculum review II, laboratory applications in secondary science education I, school experience, or practice teaching during the period of this study.

In her role as a learner, Ece encountered a spectrum of challenges, including difficulties in formulating a valid investigation and presenting a rebuttal to an invalid investigation design in the illumination activity. Additionally, she faced challenges aligning a claim with the research question and countering errors in controlling variables during the shadows activity. Notably, the law of reflection activity, image formation at the plane mirror activity, and field of view at a plane mirror activity posed no challenges for Ece.

Despite her lack of challenges in controlling variables during the shadows activity, Ece struggled to refute errors made by her classmates in this area, highlighting the interconnected nature of these challenges. Both Ece's group and another group in the class aimed to validate the same claim, but differing approaches led to discrepancies. While Ece's group adjusted the point source's position, the other group altered the obstacle's position. Despite the other group incorrectly replicating Ece's experiment, she failed to recognize the error and, consequently, could not offer a rebuttal. This emphasizes that even with similar data collection processes, one individual's absence of challenges in controlling variables does not ensure an ability to identify issues with others' variable control.

Regarding Ece's performance on the scientific process skills test, an improvement from 23 in the pre-test out of 24 to a perfect score in the post-test was observed. While the test results suggest skill improvement, engaging in new activities, and encountering different content may introduce unique challenges. Ece demonstrated high proficiency in science process skills before the study commenced. During the learning phase, initial challenges emerged due to new content, but she navigated them more effortlessly than other participants, leveraging her advanced skills. It is essential to recognize that answering skill-related test questions does not directly translate to practical skill application. Real-world situations involve exploration and novelty, requiring effective handling of uncertainties, mainly related to context and content in this study.

Crucially, Ece's prior completion of the optics and waves course, earning a DD grade, suggested unfamiliarity with the optics content. However, excelling in MSE 407 with an AA grade indicated her adeptness at overcoming challenges.

In her role as a developer, Ece grappled with a unique challenge, focusing on the intricacies of establishing connections between variables based on a theoretical foundation, with a particular emphasis on the theoretical warrant within this study. A notable observation emerges from Ece's participation in the ADI activities: while in the learner role, she encountered no obstacles during the theoretical argumentation phase. However, as she transitioned to the developer role, the challenges she faced in logically connecting variables based on the theoretical foundation, specifically regarding the theoretical warrant, became more apparent.

Furthermore, Ece's academic background before taking MSE 407, specifically completing General Physics 1 with a CC grade, raised potential challenges related to the theoretical warrant in her prepared activity. This difficulty stemmed from the necessity to establish connections between gravitational acceleration, pressure, and buoyancy—a relationship not explicitly covered in General Physics 1. This course lacked a conceptual focus and failed to establish connections between these mentioned concepts. While Ece encountered no issues in establishing relationships involving the other two variables affecting buoyancy force (object sinking volume-pressure-buoyant force and liquid density-pressure-buoyant force), she faced challenges in connecting gravitational acceleration, pressure, and buoyant force due to the abstract nature of gravitational acceleration, posing visualization difficulties. Additionally, despite the curriculum including the impact of gravity on pressure and buoyancy, comprehensive teaching on this aspect was lacking, as national exam questions seldom covered it. Ece, in interviews, acknowledged her insufficient knowledge in this subject area, contributing to challenges with the theoretical warrant.

In her capacity as a teacher, Ece confronted various challenges. Throughout her peer teaching experience, she grappled with challenges in evaluating the alignment of claims with the investigation, addressing the absence of empirical data, and guiding students, influenced by her own struggles in variable identification and control. Furthermore, she faced difficulties in requesting theoretical warrants and in querying the connection between the dependent and independent variables based on theoretical foundations.

Contrary to her experiences during peer teaching, during her high school teaching experiences, Ece did not encounter challenges related to evaluating the alignment of claims with the investigation, addressing the absence of empirical data, guiding students due to her own struggles in variable control, and requesting theoretical warrants. Nevertheless, she continued to face challenges related to guiding students due to her own difficulties in variable identification and questioning the connection between the dependent and independent variables based on theoretical foundations.

It is crucial to underscore that Ece's difficulty in guiding students with variable identification was not uniform across all student claims, manifesting specifically in scenarios involving floating objects. Two claims exemplify this challenge, where Ece perceived the submerged volume, a dependent variable, as a controlled variable due to the simultaneous alteration of two variables. This misperception occurred despite student investigations aligning with expectations.

Interestingly, Ece encountered no challenges related to variable identification in her roles as a learner and a developer in the ADI activities. However, challenges surfaced when she assumed the role of a teacher. Notably, Ece achieved full scores in the post-test administered after the learning phase of the science process skill test. This discrepancy suggests that while she excels in variable identification, challenges, particularly related to floating objects, persist as content-dependent issues, aligning with the experiences of the other two participants.

Finding 5: Argumentation skills and science process skills, along with the challenges associated with them, vary based on the specific content.

Acquiring argumentation or science process skills as a PPT does not automatically imply its mastery in all contents as highlighted by Jiménez-Aleixandre et al. (2000) and Ünal (2012). In the pertinent literature, numerous investigations affirm the development of argumentation skills in courses centered on argumentation (see Bell & Linn, 2000; Kuhn, 2010), and the enhancement of science process skills in inquiry-based courses (see Constantinou et al., 2018; Mattheis & Nakayama, 1988).

However, this research demonstrated that challenges with scientific process skills or argumentation skills, once overcome for a specific content, resurface when the content changes.

Finding 6: The success of PPTs as students in ADI activities does not guarantee their success as teachers in ADI activities.

Proficiency in science process skills and argumentation skills is contingent on the specific content. Simultaneously, possessing these skills does not guarantee the ability to notice and question them. To be an effective ADI teacher, it is imperative to possess and utilize all the mentioned skills. Consequently, the success of PPTs as students in the ADI activities does not necessarily ensure their success as teachers in the ADI activities.

Begüm's engagement in the ADI activities yielded a noteworthy insight. Assuming the role of a learner in these activities, she encountered no difficulties in understanding the theoretical foundation behind the connection between variables and applying this understanding to establish connections based on theoretical foundations. Her challenges were predominantly associated with empirical data in the learning phase. However, as she progressed from a learner to a developer and teacher, her challenges became more prominent in dealing with theoretical data.

Likewise, during the teaching phase, Banu faced a challenge that was not present in the learning phase. While in her learning phase, Banu did not encounter any issues with manipulating the independent variable, this challenge surfaced for the first time when she moved on to the teaching phase.

Additional notable insights arise from Ece's participation in the ADI activities. Ece encountered no difficulties with variable identification in her roles as a learner and a developer in the ADI activities. Nevertheless, challenges surfaced when she assumed the role of a teacher. It is also noteworthy that while in the learner role, she faced no challenges during the theoretical argumentation session. However, as she progressed from the learner to the developer and subsequently to the teacher role, the challenges in establishing the connection between variables based on the theoretical foundation, specifically the theoretical warrant, became more apparent.

5.2 Implications for Practice

The findings from the data analysis in this study indicate that the PPTs face significant challenges in argumentation skills, scientific process skills, conceptual understanding as well as skills related to noticing, guiding, and questioning based on argumentation and science process skills. Additionally, these challenges are interconnected in a sequential manner. Recognizing this as a significant issue is crucial because becoming a proficient ADI teacher cannot be achieved solely by enhancing the argumentation and scientific process skills of teachers or pre-service teachers. Notably, teachers also need to develop their noticing, guiding, and questioning skills and conceptual understanding. Addressing this multifaceted challenge is essential for effective teacher preparation and professional development in the sphere of the ADI.

Participating in the ADI courses where PPTs take on the role of students does not guarantee the improvement of their argumentation skills, scientific process skills, and noticing, guiding, and questioning based on argumentation and science process skills. While there is noticeable progress, characterizing this advancement as skill development would be inaccurate. As demonstrated by this study, argumentation and science process skills are dependent on content. Recognizing this, teacher training programs should focus on developing these skills in various contents. Additionally, ongoing professional development for teachers should consider the dynamic nature of challenges faced in different phases and activities.

Curriculum designers should take into account the identified challenges within the ADI when developing science education curricula. Emphasizing the development of argumentation and science process skills within a framework dependent on content should be integrated into curriculum goals and objectives. This ensures that educational materials and activities align with the specific challenges posed by the ADI, fostering a more realistic and effective learning experience.

The findings emphasize the importance of tailored pedagogical approaches for different phases and activities. Therefore, lecturers integrating the ADI into the undergraduate curriculum should pay special attention to the mentioned challenges. This implies a need for comprehensive lesson planning that addresses potential hurdles in specific phases. Additionally, teacher training programs should incorporate strategies to tackle challenges specific to each role, such as learner, developer, and teacher, in the ADI activities.

The alignment of challenges identified in the ADI with existing literature on argumentation and science process skills across different educational levels emphasizes the shared difficulties faced by students. This alignment supports the notion that the ADI challenges are not isolated but share commonalities with broader educational settings. Educational practices should consider this alignment to ensure a coherent and integrated approach to skill development.

The study reveals unique challenges within the ADI, such as the difficulties in formulating theoretical data and warrants. These challenges point to the need for specialized guidance in understanding and presenting theoretical foundations, which could be incorporated into teacher training programs.

The lack of noticing of students' argumentation and science process skills highlights a significant challenge in teacher guidance. This introduces an additional layer of complexity to the conversation, underscoring the importance of professional development that specifically targets the enhancement of teachers' observational skills.

5.3 Recommendations for Further Studies

Research addressing the challenges faced by students in the realms of argumentation and science process skills in science lessons is notably limited. Existing studies predominantly concentrate on the challenges encountered by middle school students in science learning through argumentation and/or inquiry-based approaches. This underscores the necessity of emphasizing research endeavors dedicated to unraveling the challenges associated with argumentation skills and scientific process skills among undergraduate students, particularly those in pre-service teacher education programs.

There is a scarcity of studies examining the challenges encountered by teachers or pre-service teachers in the preparation and teaching of argumentation and/or inquiry-based science lessons. This dearth of research suggests a need for further investigations in various contexts to unveil diverse challenges in this domain.

The exploration of the interconnected challenges regarding skills in science education is a novel contribution. This research exclusively focused on physics courses and PPTs. Expanding similar investigations to other science courses like astronomy, chemistry, biology, etc., involving both PPTs and experienced teachers across various levels, would significantly enhance the depth and scope of knowledge in the field of science education.

The research was conducted online due to the coinciding pandemic period. A valuable avenue for enrichment would involve replicating the study in a traditional live classroom setting and subsequently comparing the outcomes.

In the explanation stage of the ADI method formulated in this research, theoretical data was discreetly provided to the students, anticipating that they would observe the PPTs and apply them during the theoretical argumentation session. As an alternative iteration of the ADI, credible sources might be supplied to students during the explanation stage, enabling them to acquire trustworthy information and access theoretical data independently. This could serve as a valuable suggestion for an innovative project.

This study has demonstrated the effectiveness of the revised ADI method in an online setting. As a result, the integration of technological advancements with the

ADI method can be explored. For instance, the ADI activities could be incorporated into web-quests, providing avenues for various research endeavors.

Longitudinal studies to track the development of argumentation and science process skills over an extended period, examining how challenges persist, evolve, or diminish as PPTs transition from learners to developers and teachers in the ADI activities can be conducted.

The challenges faced by PPTs in the ADI activities with those encountered by educators using different pedagogical approaches. This could provide insights into the unique difficulties associated with the ADI and contribute to refining teacher training programs.

Effective strategies within teacher training programs to address challenges related to argumentation and science process skills in various ADI roles can be investigated.

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APPENDICES

A. Initial Stage for Each of the ADI activities

1. Aydınlanma Öğretmen Materyali

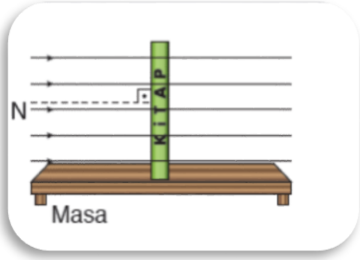
Kazanımlar
10.4.1.2. Işık şiddeti, ışık akısı ve aydınlanma şiddeti kavramları arasında ilişki kurar.
a. Deney yaparak veya simülasyonlarla aydınlanma şiddeti, ışık şiddeti, ışık akısı kavramları arasında ilişki kurulur.
b. Işık şiddeti, ışık akısı ve aydınlanma şiddeti kavramları ile ilgili matematiksel modeller verilir. Matematiksel hesaplamalara girilmez.

Derse başlamadan önce, öğrencilere deney föyünü dağıtalım. İlk adımın amacı, deney öncesi gerekli ön bilgiyi vermektir. Bunun için, argümantasyon aktivitesine aşağıda yazılı olan teorik bigiyi vererek başlayalım.

Bir ışık kaynağının birim zamanda yaydığı ışık enerjisine **ışık şiddeti** denir. **I** ile gösterilir. Birimi **candela (cd)**'dır. Özdeş ışık kaynakları için ışık şiddeti, kaynağın parlaklığı yani lambadan çıkan ışın sayısı ile ilgilidir. Şekil 1'de farklı parlaklıkta ampuller görülmektedir. Soldaki ampul daha az parlak olan, yani ışık şiddeti daha az olandır.

Şekil 1. Farklı ışık şiddetine sahip ampuller

Bir ışık kaynağının karşısına yerleştirilen yüzeye birim zamanda dik olarak gelen ışık ışınlarının miktarına **ışık akısı** denir. **Φ (fi)** ile gösterilir. Birimi **lümen (lm)**’dir (Şekil 2).



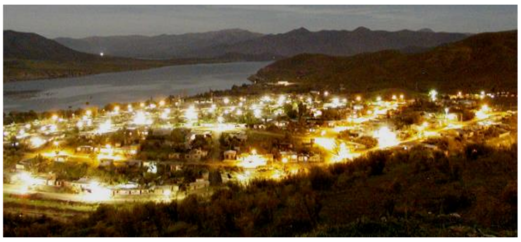
Şekil 2. Yüzeye dik olarak gelen ışınlar

Birim yüzeye düşen ışık akısı miktarına **aydınlanma şiddeti** denir. Aydınlanma şiddeti, **E** ile gösterilir. Birimi **lüx (lx)**’tür. Şekil 2’de kitabın kapağına birim zamanda gelen dik ışın miktarı ışık akısını verir. Kitap kapağını birim karelere bölersek, birim zamanda bir birim kareye gelen dik ışın miktarı aydınlanma şiddetini verir.

Şili’de Işık Kirliliği (5 dk)

Bu adımın amacı öğrencilerin derse ilgisini çekmektir. Bunun için ilk önce Şili’de ışık kirliliği fotoğrafını gösterelim (Şekil 3) ve bu konuda yazılı olan bilgiyi verelim.

Şekil 3’te Şili’de yanlış aydınlatma sonucu oluşan ışık kirliliği görüntüsünü görebiliriz. *Işık kirliliği* ışığın yanlış miktarda, yanlış yerde, yanlış yönde ve yanlış zamanda kullanılmasından kaynaklanan enerji israfıdır. Monte Patria’da yer alan göl kenarındaki bu yerleşim yeri ışık kirliliğini önleme çalışmaları için pilot bölge olarak seçilmiş ve 2005 yılında aydınlatma sistemi düzeltilmiştir.



Şekil 3. Şili'de ışık kirliliği

Siz aydınlatma mühendisi olsaydınız ve göreviniz bu bölgedeki ışık kirliliğini önlemek olsaydı, yapacağınız değişiklikler neler olurdu? Neden?

Bu soruyu cevaplayabilmek için ilk olarak aşağıdaki araştırma sorusunu cevaplamalıyız.

Araştırma Sorusu

Şimdi, araştırma sorusunu soralım.

Araştırma sorusu: Aydınlanma şiddetini etkileyen faktörler nelerdir, nasıl etkilerler? Verdiğiniz cevabın altında yatan teori nedir?

2. Gölge Öğretmen Materyali

Kazanımlar

10.4.2.1. Saydam, yarı saydam ve saydam olmayan maddelerin ışık geçirme özelliklerini açıklar.

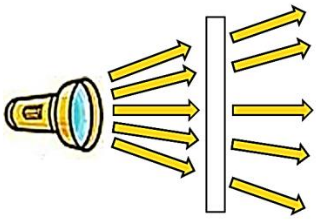
a. Öğrencilerin gölge ve yarı gölge alanlarını çizmeleri ve açıklamaları sağlanır.

b. Gölge ve yarı gölge ile ilgili matematiksel hesaplamalara girilmez.

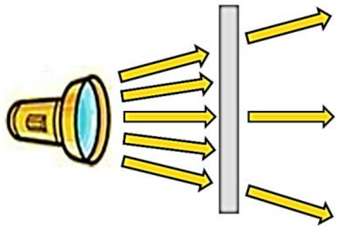
Derse başlamadan önce, öğrencilere deney föyünü dağıtalım. İlk adımın amacı, deney öncesi gerekli ön bilgiyi vermektir. Bunun için, argümantasyon aktivitesine aşağıda yazılı olan teorik bigiyi vererek başlayalım.

Işık Geçirgenliklerine Göre Maddeler (5dk)

Üzerine gelen ışığı geçiren maddelere **saydam maddeler** denir (Şekil 1). Örneğin cam görünür ışığa göre saydam maddedir. Üzerine gelen ışığın bir kısmını geçirip bir kısmını tutan ya da yansıtan maddelere **yarı saydam maddeler** denir (Şekil 2). Yarı saydam maddeler ışığın yayılarak geçmesine izin verir. Örneğin buzlu cam ve yağlı kâğıt görünür ışığa göre yarı saydam maddelerdir. Üzerine gelen ışığı geçirmeyen maddelere **saydam olmayan (opak) maddeler** denir (Şekil 3). Etrafımızdaki birçok cisim saydam olmayan maddeden meydana gelmiştir. Örneğin tahta ve metal ışığı geçirmezler, çünkü saydam değildirler.



Şekil 1.Saydam madde



Şekil 2.Yarı saydam madde

Şekil 3.Opak madde

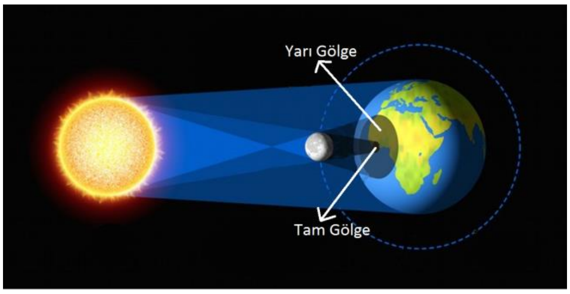
Tam Gölge ve Yarı Gölge

Ortaokulda öğrendiğimiz gibi, maddeler üzerine düşen ışığı geçirmediğinde, maddenin arka tarafında karanlık bir bölge oluşumuna neden olurlar. Işığın ulaşamadığı bu karanlık bölgeye **gölge** denir. Eğer karanlık bölgeye hiç ışık ulaşmıyorsa, oluşan gölgeye **tam gölge**; kısmen ışık ulaşıyorsa, oluşan gölgeye **yarı gölge** denir.

Tutulma Hattı (10 dk)

> *Bu adımın amacı öğrencilerin derse ilgisini çekmektir. Bunun için ilk önce 29 Mart 2006 yılında gerçekleşen Güneş tutulmasının fotoğraflarını gösterelim ve aşağıda yazılı olan bilgiyi verelim.*

Güneş tutulması; Ay, Dünya ile Güneş arasına girdiğinde meydana gelir. Bu durumda; Ay'ın gölgesi Dünya üzerine düşer ve biz Güneş tutulması gözlemleriz (Şekil 4). Dünya üzerindeki gölgede hem tam gölgeyi (gölgenin merkezindeki hiç ışık almayan kısım) hem yarı gölgeyi (tam gölgenin etrafındaki kısmen ışık alan kısım) birlikte görebiliriz.



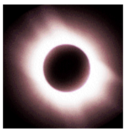
Şekil 4. Güneş Tutulması çizimi

Şekil 5'te 2006 yılında Türkiye'de bazı şehirlerde gözlemlenen Güneş tutulmasının aşama aşama çekilmiş fotoğraflarının birleştirilmiş halini görmekteyiz.

Şekil 5. 2006 yılında gerçekleşen Güneş tutulması'nın fotoğrafları (Boğaziçi üniversitesi)

Görüldüğü gibi Ay'ın, Güneş önüne geçmesi esnasında ilk olarak parçalı Güneş tutulması gözlemleriz; yani Ay, Güneş'in bir parçasını kapatmış olarak görürüz (Şekil 6). Ardından tam Güneş tutulması gözlemleriz; yani Ay, Güneş'i tamamen kapatmış ve Güneş ile aynı boyutta görürüz (Şekil 7). Sonra tekrardan parçalı Güneş tutulması gözlemleriz. Tam Güneş tutulması sırasında Güneş'in etrafında gördüğümüz ışıklı alan Güneş'in atmosferidir.

Şekil 6. Parçalı Güneş Tutulması

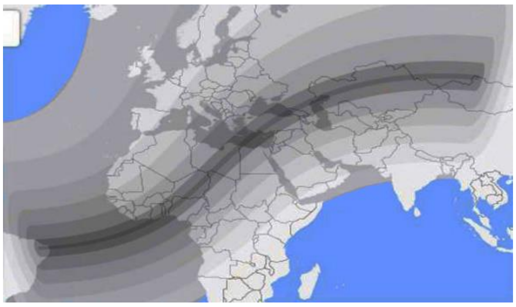


Şekil 7.Tam Güneş Tutulması

Bütün Güneş tutulmalarında, tam tutulma gözlemlemeyebiliriz. Başka bir deyişle, bazı Güneş tutulmaları parçalı tutulma olarak başlar ve parçalı tutulma olarak biter (Şekil 8).

Şekil 8. Parçalı Güneş tutulması

Şekil 9'da gösterilen haritada, 2006 yılında gerçekleşen Güneş tutulmasının tüm hattını yani tutulmayı hangi ülkelerin izleyebildiğini görebiliriz. Haritadaki gri bölge, tutulmanın gözlemlendiği bölgedir. Dikkatle bakarsanız tüm Türkiye halkı tutulmayı gözlemlemiş ancak Türkiye'den gözlemlenen Güneş tutulması haritada farklı gri tonlarında gösterilmiştir.



Şekil 9. 2006 yılı Güneş tutulması hattı

Türkiye'ye daha yakından bakalım (Şekil 10). Tutulma hattında örneğin; Antalya çok koyu bir gri ton üzerinde iken, Ankara daha açık bir gri ton üzerindedir.

Şekil 10. 2006 yılı Güneş tutulması hattında Türkiye

Güneş tutulması hattında farklı tonlar kullanılmasının nedeni nedir?

Bu soruyu cevaplayabilmek için ilk olarak aşağıdaki araştırma sorusunu cevaplamalıyız.

Araştırma Sorusu

Şimdi, araştırma sorusunu soralım.

Araştırma sorusu: Tam gölge ve yarı gölge oluşumu arasındaki fark/farklar nelerdir? Verdiğiniz cevabın altında yatan teori nedir?

3. Yansıma Kanunları Öğretmen Materyali

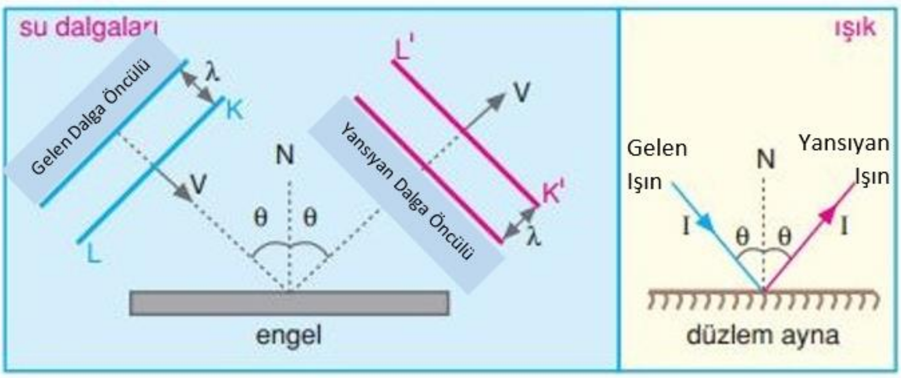
Kazanımlar
10.4.3.1. Işığın yansımasını, su dalgalarında yansıma olayıyla ilişkilendirir.
a. Yansıma Kanunları üzerinde durulur.
b. Işığın düzgün ve dağınık yansımasının çizilerek gösterilmesi sağlanır.
c. Görme olayında yansımanın rolü vurgulanır.

Derse başlamadan önce, öğrencilere deney föyünü dağıtalım. İlk adımın amacı, deney öncesi gerekli ön bilgiyi vermektir. Bunun için, argümantasyon aktivitesine aşağıda yazılı olan teorik bigiyi vererek başlayalım.

Yansıma (3 dk)

Bildiğiniz gibi, ışınların herhangi bir yüzeye çarpıp doğrultu değiştirerek bulunduğu ortama geri dönmesine **yansıma** denir.

Işık ışını düz bir yüzeyle karşılaştığında tıpkı bir su dalgasının düz bir engelle karşılaştığında davrandığı gibi davranır (Şekil 1). Su dalgalarında yansıma olayını açıklamak için **dalga öncülleri** ve **ilerleme yönü** kullanılırken, ışıkta yansıma olayını açıklamak için **ışın** kullanılır. Ortaokulda öğrendiğimiz gibi; ışık kaynağından çıkıp yüzeye çarpan ışına **gelen ışın**, yüzeyden doğrultu değiştirerek bulunduğu ortama geri dönen ışına **yansıyan ışın** denir. Gelen ışının, yüzeye çarptığı noktadan yüzeye dik çizilen doğruya **yüzeyin normali** denir. Gelen ışın ile normal arasındaki açıya **gelme açısı**, normal ile yansıyan ışın arasındaki açıya **yansıma açısı** denir.

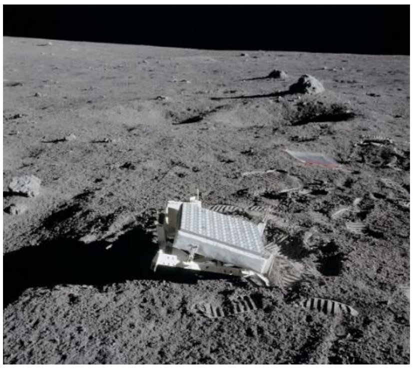


Şekil 1. Doğrusal su dalgasının ve ışığın, doğrusal engelden yansıması

Ay’daki Ayna (7 dk)

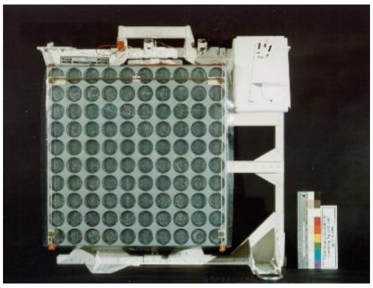
Bu adımın amacı öğrencilerin derse ilgisini çekmektir. Bunun için ilk önce Ay’a yerleştirilen ayna sistemi hakkında aşağıdaki bilgiyi verelim ve Apollo 14 kapsamında yerleştirilen ayna sisteminin fotoğraflarını (Şekil 2-Şekil 5) gösterelim.

Amerika ve Rusya, ayrı ayrı yaptıkları uzay yolculukları sırasında Ay’ın bazı konumlarına **küçük düzlem aynalardan** oluşan **ayna sistemleri** yerleştirmişlerdir. Şekil 2’de Amerika’nın, Apollo 14 ile Ay’a yerleştirdiği ayna sisteminin fotoğrafını görebiliriz. Bu aynalar, Ay üzerine sabitlenmişlerdir. Hiçbir şekilde hareket edemezler, aynalarını hareket ettiremezler.



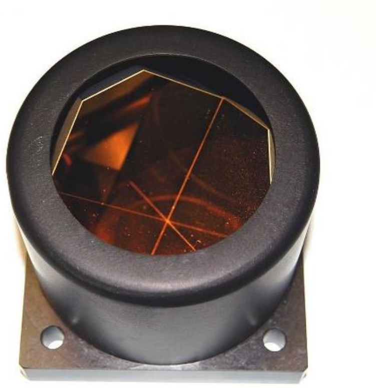
Şekil 2. Ay üzerindeki ayna

Şekil 3, Apollo 14 astronotlarının eğitimi için kullanılan modeli göstermektedir, Ay’a yerleştirilen modelin benzeridir. Yuvarlak görünen kısımlar, **3 tane düzlem aynanın** birleştirilerek oluşturulan ayna sisteminin bulunduğu kısımlardır.



Şekil 3. Ay'a yerleştirilen ayna modeli

Ayna sistemine daha da yakından bakalım (Şekil 4). Bu kısım, 3 tane düzlem aynanın üçünün de birbirine dik olacak şekilde birleştirilmesiyle oluşturulmuştur.



Şekil 4. Ay'daki ayna sisteminin bir yansıtıcı bölümü

3'lü ayna sistemi isimli videoyu izleyelim.

Bilim insanları, Dünya'dan Ay'daki bu aynalar üzerine lazer ışını göndermektedir. Videoda da gördüğümüz gibi ışın bu yuvarlak kısımlara ulaşıp (Şekil 4), bu aynalar üzerinden yansıyarak Dünya'ya geri dönmektedir. İşin ilginç tarafı, Dünya'dan Ay'a gönderilen ışın ile Ay'dan Dünya'ya dönen ışın, **aynaya hangi açı ile ulaştığı fark etmeksizin her zaman birbirine paraleldir**. Dolayısı ile ışın gönderildiği yere ya da gönderildiği noktanın hemen yakınına geri dönmektedir. Bu sayede bilim insanları, Dünya ve Ay arasındaki mesafeyi hesaplamaktadırlar. İzlediğimiz videoda, dikkat ettiyseniz ışın sadece iki aynadan yansıyarak gittiği yolun paralelinden geri döndü. Birbirine dik olarak yapıştırılmış iki ayna, giden ışını aynı doğrultuda geri döndürmek için yeterlidir.

Dünya'dan yüz binlerce km uzaklıktaki Ay üzerinde bulunan ayna sistemine gönderilen lazer ışınları nasıl oluyor da yansıdıktan sonra, aynaya gittiği yolun **paralelinden** geri dönüyor?

Bu soruyu cevaplayabilmek için ilk olarak aşağıdaki araştırma sorusunu cevaplamalıyız.

Araştırma Sorusu

Şimdi, araştırma sorusunu soralım.

Araştırma sorusu: Yansıma Kanunları nelerdir? Verdiğiniz cevabın altında yatan teori nedir?

4. Düzlem Aynada Görüntü Oluşumu Öğretmen Materyali

Kazanımlar
10.4.4.1. Düzlem aynada görüntü oluşumunu açıklar.
a. Düzlem aynada görüntü özellikleri, yapılan çizimler üzerinden açıklanır.
b. Kesişen ayna, aynanın döndürülmesi, hareketli ayna ve hareketli cisim konularına girilmez.

Derse başlamadan önce, öğrencilere deney föyünü dağıtalım. İlk adımın amacı, deney öncesi gerekli ön bilgiyi vermektir. Bunun için, argümantasyon aktivitesine aşağıda yazılı olan teorik bigiyi vererek başlayalım.

Düzlem Ayna (2 dk)

Ayna, bir camın arkası alüminyum ya da gümüş gibi bir metalle sırlanarak yapılan yansıtıcı yüzeylerdir. **Düzlem aynalar**, yansıtıcı yüzeyi düz olan aynalardır. Üzerine gönderilen paralel ışık demetini, paralel olarak geldiği ortama yansıtırlar. Evlerimizde kullandığımız duvar aynaları, düzlem aynalara örnektir (Şekil 1).

Şekil 1. Düzlem Ayna

Uçuran Sandık (3 dk)

Bu adımın amacı öğrencilerin derse ilgisini çekmektir. Bunun için ilk önce Uçuran Sandık isimli videoyu öğrencilere izletelim ve ardından aşağıda yazılı olan soruyu öğrencilere soralım.

Nasıl oluyor da videoda izlediğimiz bu öğrenci havada asılı kalıyor (Şekil 2)?

Şekil 2. Havada asılı kalan öğrenci

Bu soruyu cevaplayabilmek için ilk olarak aşağıdaki araştırma sorusunu cevaplamalıyız.

Araştırma Sorusu

Şimdi, araştırma sorusunu soralım.

Araştırma sorusu: Düzlem aynada görüntü özellikleri nelerdir? Verdiğiniz cevabın altında yatan teori nedir?

5. Görüş Alani Öğretmen Materyali

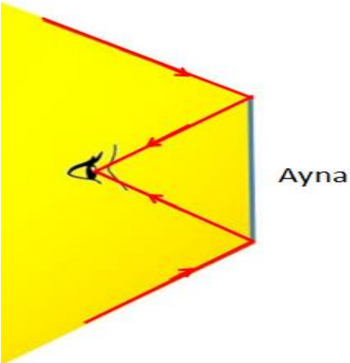
Kazanımlar

10.4.4.1. c. Deney ve simülasyonlarla görüş alanına etki eden değişkenler ile ilgili çıkarım yapılması sağlanır. Çıkarım yapılırken saydam ve saydam olmayan engeller de dikkate alınır. Matematiksel hesaplamalara girilmez.

Derse başlamadan önce, öğrencilere deney föyünü dağıtalım. İlk adımın amacı, deney öncesi gerekli ön bilgiyi vermektir. Bunun için, argümantasyon aktivitesine aşağıda yazılı olan teorik bigiyi vererek başlayalım.

Görüş Alanı (5dk)

Bir aynada görebildiğimiz alana **görüş alanı** denir. Şekil 1'de sarıya boyalı olarak gösterilen alan, aynaya bakan kişinin görüş alanıdır.



Şekil 1. Görüş alanı

Sürücü Aynaları

Bu adımın amacı öğrencilerin derse ilgisini çekmektir. Bunun için, ilk önce sürücü aynalarının fotoğraflarını (Şekil 2) gösterelim ve ardından aşağıda yazılı olan bilgiyi verelim.

Bir başkasına ait arabayı kullanmadan önce koltuğun pozisyonunu ve aynaları kendimize göre ayarlamamız gerekir (Şekil 2). Çünkü bizim boyumuzdan farklı bir boya sahip bir kişinin ayna ayarları bizim için uygun değildir.

Şekil 2. Sürücü aynaları

Koltuğun pozisyonunu ve aynaların yönünü değiştirdiğimizde değişen görüş alanımızdır. Nasıl değişir? Cevabınızın teorik temeli nedir?

Bu soruyu cevaplayabilmek için ilk olarak aşağıdaki araştırma sorusunu cevaplamalıyız.

Araştırma Sorusu

Şimdi, araştırma sorusunu soralım.

Araştırma sorusu: Düzlem aynada görüş alanına etki eden değişkenler nelerdir, nasıl etkilerler? Verdiğiniz cevabın altında yatan teori nedir?

B. Materials of ADI

Teacher Guide

Görüş Alani Öğretmen Materyali

Kazanımlar

10.4.4.1. c. Deney ve simülasyonlarla görüş alanına etki eden değişkenler ile ilgili çıkarım yapılması sağlanır. Çıkarım yapılırken saydam ve saydam olmayan engeller de dikkate alınır. Matematiksel hesaplamalara girilmez.

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Görüş Alanı (5dk)

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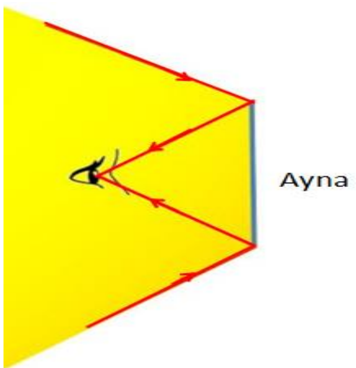

Şekil 1. Görüş alanı

Sürücü Aynaları

Bu adımın amacı öğrencilerin derse ilgisini çekmektir. Bunun için, ilk önce sürücü aynalarının fotoğraflarını (Şekil 2) gösterelim ve ardından aşağıda yazılı olan bilgiyi verelim.

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Araştırma Sorusu

Şimdi, araştırma sorusunu soralım.

Araştırma sorusu: Düzlem aynada görüş alanına etki eden değişkenler nelerdir, nasıl etkilerler? Verdiğiniz cevabın altında yatan teori nedir?

Deney Zamanı (15dk)

2 kişilik gruplar oluşturalım.
Öğrencilerden, bu adımda araştırma sorusunu cevaplamak için, aşağıda verilen deney düzeneklerinden en az bir tanesini seçip, ona göre iddia yazmalarını ve veri toplamalarını isteyelim. Toplanan tüm veriler için öğrencilerden gözlemlerini çizmelerini, fotoğrafını çekmelerini ya da yazılı olarak aktarmalarını isteyelim ve tüm bunları öğrenci föyündeki deney kutusuna not etmelerini isteyelim.
***İddia**, kanıt sunmaksızın ortaya atılan ifadedir. Öğrenciler; iddialarını yapacakları deneyin muhtemel sonucu olarak, deneyden önce yazacaklardır. Bu iddiaların bazıları deney sonrası kanıtlarla desteklenirken, bazıları ise çürütülecektir.*
Öğrencilerin araştırma sorusuna verdikleri tahmini cevaplar doğrultusunda iddialarını oluşturmalarına yardım edelim. Öğrencilerden gelen her anlamlı iddiayı not edelim. Herkes istediği şekilde deney yapabilir. Herkesin aynı deneyi yapma zorunluluğu olmadığı gibi, aynı sonuçlara ulaşma zorunluluğu da yoktur.

Elimizdeki materyaller ile deney tasarlama zamanı. İlk olarak iddialarımızı oluşturalım. Daha sonra iddialarımızın doğruluğunu kontrol etmek amaçlı deneyimize başlayalım. Gözlemlerimizi çizim, fotoğraf ya da yazılı olarak kaydedelim.

Araştırma sorusunu cevaplayabilmek için nasıl bir düzenek oluşturabiliriz?

→Bir aynanın önünde yer değiştirerek (sağa ya da sola ilerleyerek) gözlem yapabiliriz, aynaya yaklaşıp uzaklaşarak gözlem yapabiliriz ya da boyutları farklı başka aynalar kullanarak gözlem yapabiliriz. Görüşü engelleyen materyalleri aradan kaldırabiliriz.

Kullanılabilecek örnek malzemeler:

- Düzlem ayna (Farklı boyutlarda iki düzlem ayna)

Dikkat!

Öğrencilere aşağıdaki uyarıyı yapalım.

- Aynalar ile elimizi kesmeyelim.

Bilimsel Tartışma (15 dk)

Bu adımda, öğrenciler kendi iddialarını destekleyen ya da çürüten kanıtlarını öğrenci föyündeki deney kutusuna yazıp, sınıfla paylaşacaklar ve birbirlerini eleştirecekler. Bu amaçla, öğrencilerin argümanlarını (iddia ve kanıt) sorgulayarak, sınıfta tartışma ortamı oluşturalım. Eğer iddia ve kanıtlar yetersizse öğrencilere aşağıdaki argümantasyon güçlendirme sorularından uygun olanlarından birini soralım. Gerekirse, öğrencilere birbirlerinin ve kendilerinin kanıtlarını kontrol etme, deney süreçlerini açıklama fırsatı verelim.

Öğrenci föyüne yazdığımız argümanlarımızı (iddia ve kanıt) sınıfla paylaşarak bilimsel tartışmaya başlayalım. Argümanlarımız iddialar, iddialarımızı destekleyen kanıtları içermelidir. İddialar, grubumuzun araştırma sorusuna verdiği cevaplardır. Kanıtlar, topladığımız verilerin yorumu ve analizidir.

Kimler, neyi incelemişti? İddianızı hatırlatır mısınız? Ne buldunuz? Kanıtlarınız nelerdir? Bu kanıtlara nasıl ulaştınız?

Öğrencilerden gelmesi muhtemel iddialar ve kanıtlar:

İddia 1: Düzlem aynaya yaklaştığımızda aynada gördüğümüz alan büyür.

Kanıt 1: Düzlem aynada görünen alan çizimi /fotoğrafı / yazılı anlatımı ve yorumu.

İddia 2: Düzlem aynanın solundan sağına hareket etttiğimizde sol tarafı görürken, sağından soluna hareket ettiğimizde sağ tarafı görürüz.

Kanıt 2: Düzlem aynada görünen alan çizimi /fotoğrafı / yazılı anlatımı ve yorumu.

İddia 3: Düzlem ayna büyüdükçe görüş alanı büyür.

Kanıt 3: Düzlem aynada görünen alan çizimi /fotoğrafı / yazılı anlatımı ve yorumu.

Argümantasyon Güçlendirme Soruları

- İddianızın doğru olduğuna dair kanıtınız varsa, arkadaşınızın iddiasını nasıl çürütebilirsiniz?
- Hangi bilgi arkadaşlarının iddiasının yanlış olduğunu kanıtlar?
- Sınıfta arkadaşlarımızın iddiasının yanlış olduğunu kanıtlayabilecek biri var mı?
- Bu iddiaya karar vermeden önce, grubunuzda tartıştığınız başka iddialar var mıydı? Diğer iddialardan neden vazgeçtiniz?
- İddianızın geçerli olduğundan ne kadar eminsiniz? Emin olmak için ne yapabilirsiniz?
- Verileri nasıl topladınız? Neden bu yöntemi kullandınız? Neden bu verileri topladınız?
- Topladığınız verilerin güvenilir olduğundan emin olmak için ne yaptınız? Hata payınızı düşürmek için ne yaptınız?
- Verileri nasıl analiz ettiniz? Neden o şekilde yapmaya karar verdiniz?
- Kanıtlarınızı farklı yorumlayabilir miydiniz? Kanıtlarınızı doğru yorumladığınızdan emin misiniz?
- Neden kanıtlarınızı bu şekilde sunmaya karar verdiniz?

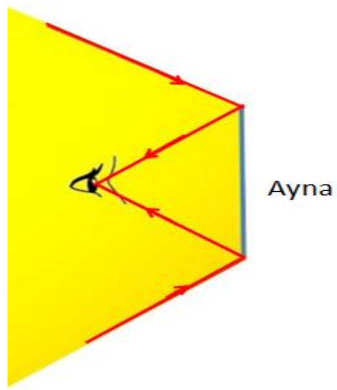
Eğer, yukarıda bahsi geçen iddiaların benzeri iddialar öğrenciler tarafından oluşturulmadıysa ve deneyi yapılmadıysa öğretmen tarafından yapılmalıdır. Bu durumda;
'Şimdiye kadar sınıfta yapılan deneyler, araştırma sorusunu cevaplamak için yeterli mi? Başka bir iddiada bulunmaya gerek var mı?' gibi sorularla öğrencileri sorgulayalım ve deneyi öğretmen olarak biz yapalım.

Görüş Alanı (10 dk)

Bu adımda, öğrencilere yaptıkları deneyin altında yatan teorik bilgiyi açıklayalım.

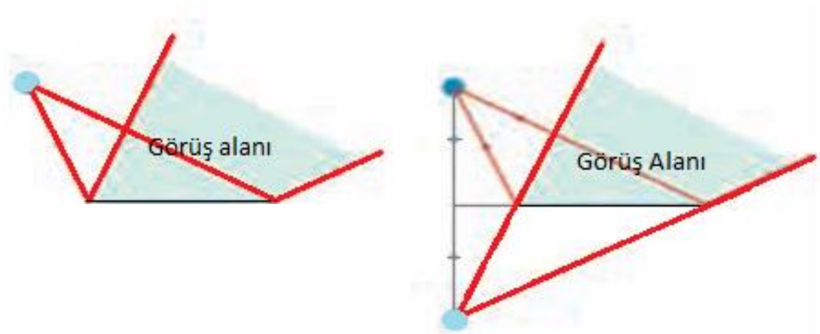
Artık bu işin fiziğini konuşabiliriz. Kanıtlarımızın neden iddiaları desteklediğini konuşabilmek ve başta sorulan araştırma sorusunu cevaplayabilmek için görüş alanının ne olduğunu öğrenmemiz gereklidir.

Az önce öğrendiğimiz gibi, bir aynada görebildiğimiz alana **görüş alanı** denir. Şekil 1'de sarıya boyalı olarak gösterilen alan, aynaya bakan kişinin görüş alanıdır. Görüş alanında bulunan bütün cisimlerden (eğer arada opak bir engel yok ise) aynaya gelen ışınlar, ayna üzerinden yansır, gözümüze gelir ve görürüz. Görüş alanının sınırlarını, aynanın uçlarından gözümüze gelen ışınlar belirler. Çünkü bu ışınlar, aynadan yansıyarak gözümüze gelen son ışınlardır. Bunlara uç ışın denir. Şekil 1'de kırmızı olarak çizilen ışınlar, görüş alanının sınırlarını belirleyen uç ışınlardır. Kırmızı ışınların arasındaki sarı bölgedeki ışınlar aynaya gelip, yansıma sonucu gözümüze gelir ve sarı bölgeyi görürüz. Kırmızı ışınlar dışındaki beyaz bölgeden aynaya gelen ışınlar, yansıma sonucu gözümüze gelmez ve beyaz bölgeyi göremeyiz. Kısacası sarı bölge bizim görüş alanımızdır. Görüş alanını bulmak istediğimizde, ilk olarak gözümüze aynanın uç noktalarından geldiğini düşündüğümüz ışınları çizeriz. Ardından bu yansıyan ışınların, aynaya gelen ışınlarını çizeriz.



Şekil 1. Görüş alanı

*Kısa yol: Görüş alanını bulmak için en kısa yol, bakan kişinin ayna düzlemine göre simetriğini alıp (çünkü aynaya bakan kişinin görüntüsü, düzlem aynaya göre simetriğidir.), bakan kişinin gözünden aynanın uçlarından geçecek şekilde çizgi çizmektir. Aynanın ön tarafında, çizgiler arasında kalan alan, aynaya bakan kişinin görüş alanıdır (Şekil 3).



Şekil 3. Görüş alanı bulmanın kısa yolu

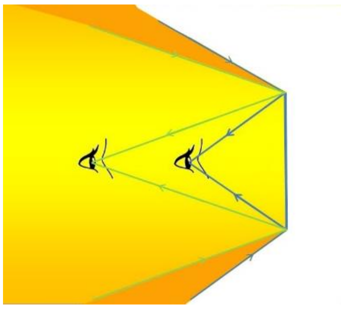
Bilimsel Tartışma 2 (20 dk)

Şimdi, öğrencilere gösterdikleri kanıtların iddiaları neden desteklediğini soralım ve cevaplarını öğrenci föyündeki deney kutusuna yazmalarını isteyelim. Öğrencilerin sorulara verdikleri cevapları dinledikten sonra, kendi nedenlerimizi verelim. Verilen teorik bilgi bu soruları cevaplamak için yeterli olacaktır. Son olarak, öğrencilere dersin başında sorulan araştırma sorusunu tekrar soralım.

Deneylerimizden elde ettiğimiz kanıtlar bazılarımızın iddialarını çürütürken, bazılarımızın iddialarını destekledi. Peki, neden? Şimdi, bunu öğrenme vakti. Bunun için, öğrendiğimiz teorik bilgiyi kullanarak sorulan soruları cevaplayalım.

Düzlem aynaya yaklaştığımızda görüş alanı neden büyür?

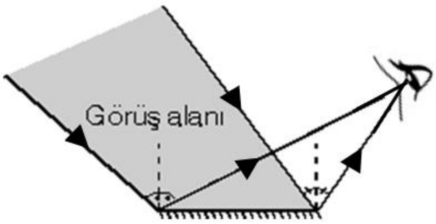
- Çünkü aynaya yaklaştığımızda önceden ayna üzerinden yansıyarak gözümüze ulaşmayan ışınlar (turuncu bölgeden gelen ışınlar), ulaşmaya başlar (Şekil 4). Şekilde aynaya uzak olan gözlemci sadece sarı alanı görebilirken, yaklaştığında sarı alana ek olarak turuncu alanı da görmeye başlar.



Şekil 4. Farklı uzaklıklardaki gözlemciler için görüş alanı

Düzlem aynanın solundan sağına doğru hareket ettiğimizde neden sol tarafı, sağından soluna doğru hareket ettiğimizde neden sağ tarafı görürüz?

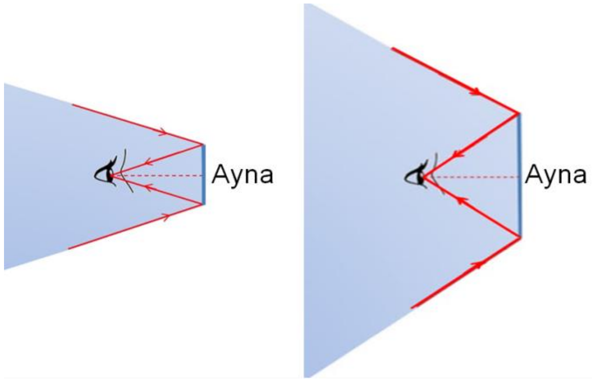
- Çünkü biz sağa hareket ettiğimizde, sol taraftan aynaya gelen ışınlar yansıyarak gözümüze ulaşabilirken; biz sola hareket ettiğimizde, sağ taraftan gelen ışınlar yansıyarak gözümüze ulaşabilir (Şekil 5).



Şekil 5. Farklı yönlerdeki gözlemciler için görüş alanı

Düzlem ayna büyüdükçe görüş alanı neden artar?

- Çünkü ayna küçükken aynaya ulaşamayan ışınlar, aynaya ulaşmaya ve oradan yansıyarak gözümüze ulaşmaya başlar (Şekil 6).



Şekil 6. Farklı boyutlardaki aynalar için görüş alanı

Araştırma Sorusuna Dönüş

Şimdi, öğrencilere dersin başında sorduğumuz araştırma sorusunu tekrar soralım ve cevaplarını öğrenci föyündeki deney kutusundaki sonuç kısmına yazmalarını isteyelim.

Araştırma sorusu: Düzlem aynada görüş alanına etki eden değişkenler nelerdir, nasıl etkilerler? Verdiğiniz cevabın altında yatan teori nedir?

Düzlem aynaya yaklaştığımızda görüş alanı büyür, çünkü önceden ayna üzerinden yansıyarak gözümüze ulaşmayan ışınlar, ulaşmaya başlar.

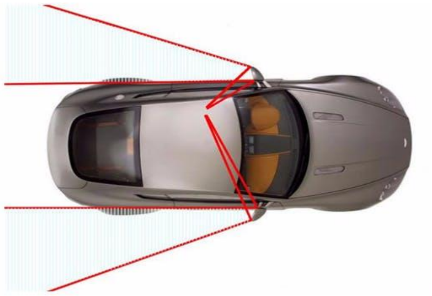
Düzlem aynanın önünde sağa hareket ettiğimizde sol alanı, sol tarafa hareket ettiğimizde sağ tarafı görürüz, çünkü biz sağa hareket ettiğimizde, sol taraftan yansıyan ışınlar gözümüze ulaşırken; sola hareket ettiğimizde, sağ taraftan yansıyan ışınlar gözümüze ulaşır.

Düzlem ayna büyüdükçe görüş alanı artar, çünkü ayna küçükken aynaya ulaşamayan ışınlar, aynaya ulaşmaya ve oradan yansıyarak gözümüze ulaşmaya başlar.

Sürücü Aynalarına Dönüş

O halde, koltuğun pozisyonunu ve aynaların yönünü değiştirdiğimizde görüş alanı nasıl değişir? Cevabınızın teorik temeli nedir?

- Aynanın soluna oturduğumuzda, aynayı sağa yönlendirerek, aynadan daha önce göremediğimiz sağ tarafı görebiliriz. Ya da sol kenarımızdaki dikiz aynasını daha da sola yönlendirdiğimizde, daha önce görmediğimiz sol tarafı görebiliriz. Koltuğumuzu yukarı çıkartarak, aynadan daha önce göremediğimiz alt tarafı görebiliriz. Koltuğu ön tarafa yaklaştırarak, dolayısı ile aynaya yaklaşarak, görüş alanımızı büyütebiliriz. Geri görüşü sağlayan dikiz ve yan aynalara şoför koltuğundan baktığımızda arkamızdaki trafiği sorunsuz bir şekilde görebiliyor olmamız gerekir (Şekil 7). Görüş alanımızı, arkamızdaki trafiği görebilecek şekilde ayarlamalıyız.



Şekil 7. Sürücünün dikiz aynalarından görüş alanları

Örnek (15 dk)

Bu adımda, öğrencilere öğrendikleri teorik bilgiyi uygulama fırsatı sunalım.

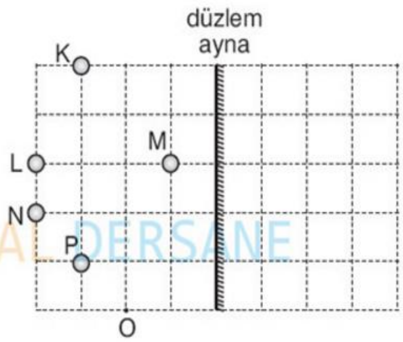
Peki, Şekil 1'deki gibi aynaya bakıyor olsaydık, sarı ile boyalı alandaki tüm cisimleri aynaya bakarak görebilir miydik? Neden?

- Hayır. Görüş alanımızda da olsa, cisimden yansıyan ışınlar gözümüze ulaşmıyorsa o cismi göremeyiz. Örneğin Şekil 8'de aynaya bakan çocuk, hemen arkasında bulunan toz pembe battaniyenin orta kısmını göremez, sadece kenar kısımlarını görür. Görmek için tek şart, battaniyeden yansıyan ışınların, ayna üzerinden yansıyarak çocuğun gözüne gelmesi. Battaniyenin orta kısmından yansıyan ışınların, çocuk tarafından aynaya ulaşması engellenir, dolayısı ile bu ışınlar çocuğun gözüne ulaşamaz. Sonuç olarak orta kısmı göremez.

Şekil 8. Aynaya bakan çocuk

Örnek: (2007 ÖSS)

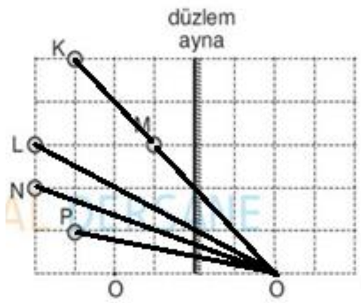
Düşey kesiti şekildeki gibi olan düzenekte, O noktasından aynaya bakan bir gözlemci düzlem ayna önüne konan K, L, M, N, P çelik bilyelerinden hangisinin görüntüsünü <u>göremez</u>?



A) K B) L C) M D) N E) P

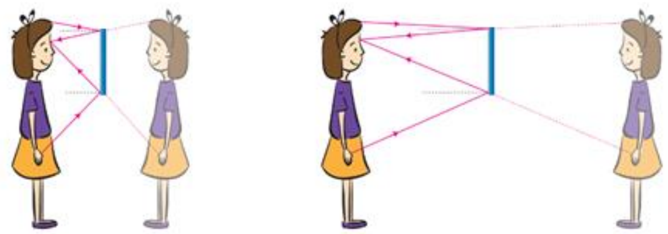
- K, tüm bilyeler gözlemcinin görüş alanında olmasına rağmen K üzerinden yansıyan ışınlar M cismine çarpar ve aynaya ulaşamaz.

- Kısa yol: O noktasının, düzlem aynaya göre simetriğini alalım. Çünkü O noktasından bakan gözlemcinin aynadan gördüğü görüntü ile, ayna olmadığı durumda O noktasının simetrisinden baktığındaki görüntü aynıdır (Şekil 3'ü hatırlayalım.). O noktasını ve düzlem aynayı yok gibi düşünelim. Gözlemcinin, bilyeleri görebilmesi için, bilyelerden gözlemcinin gözüne ışın gelmelidir. Bu sebeple, bilyelerden, O'nun simetrisine ışın çizelim. L,M,N ve P'den yansıyan ışınlar gözlemciye ulaşırken; K'dan yansıyan ışınlar M bilyesi tarafından engellenir. Gözlemci K'yı göremez.



Örnek: Düzlem aynaya yaklaştığımızda/uzaklaştığımızda, vücudumuzun gördüğümüz bölümü değişir mi?

- Hayır. Daha iyi anlamak için Şekil 9'u inceleyelim. Sol taraftaki görselde aynaya yakın duran kız, sağ taraftaki görselde aynaya uzak durmaktadır. İki görselde de uç ışınlar yardımıyla kızın görüş alanını çizersek, başının tepesinden ellerine kadar olan bölgenin görüş alanı içerisinde olduğunu görürürüz. Aynaya olan uzaklığımızı değiştirsek de, vücudumuzun aynada gördüğümüz bölümü her zaman aynıdır.



Şekil 9. Aynaya olan uzaklığımızın vücudumuzun gördüğümüz bölümüne etkisi

Son olarak, öğrencilerin föylerini öğretmene teslim etmelerini isteyelim ve konu ile ilgili çalışma kağıdını öğrencilere dağıtalım.

Student Activity Sheet

Görüş Alani Deney Föyü

Araştırma sorusu: Düzlem aynada görüş alanına etki eden değişkenler nelerdir, nasıl etkilerler? Verdiğiniz cevabın altında yatan teori nedir?

Örnek Deney Kutusu

Araştırma Sorusu: Aydınlanma şiddetini etkileyen faktörler nelerdir, nasıl etkilerler? Verdiğiniz cevabın altında yatan teori nedir?

İddia: Lamba ile aydınlanan yüzey arasındaki uzaklık azalırsa, yüzeyin aydınlanma şiddeti artar.

Kanıt:

Lamba ile aydınlanan yüzey arasındaki uzaklık	Aydınlanma şiddeti
20 cm	1300 lüx
40 cm	190 lüx
70 cm	55 lüx

Bu soruyu cevaplamak için ne yaptık?: Telefon feneri ile masamızın üzerini aydınlattık ve aydınlanan yüzeyin aydınlanma şiddetini ölçmek için yüzeye ışık ölçer koyduk. Lamba ile ışık ölçer arasındaki dik uzaklığı değiştirdik, ışık ölçerde okunan değeri not aldık. Işık ölçerden okuduğumuz değer aydınlanma şiddeti idi. Uzaklık bizim bağımsız değişkenimiz, aydınlanma şiddeti bağımlı değişkenimiz idi. Işık şiddeti ise kontrollü değişkenimizdi. Lamba ile ışık ölçer arasındaki uzaklığı değiştirirken, deneyde diğer her şeyi sabit tuttuk. Çünkü, bir deneyde aynı anda iki ya da daha fazla değişken değiştiremeyiz. Eğer değiştirirsek, aydınlanma şiddetinde olan değişikliğin hangi değişkenden olduğunu anlayamayız.

Neden: İddiamız doğrulandı çünkü lamba ile ışık ölçer arasındaki uzaklık azalırsa, ışık ölçer yüzeyine daha fazla ışın gelir, ışık akısı artar dolayısı ile aydınlanma şiddeti artar.

Sonuç: Sınıfta yapılan tüm deneylerin sonuçlarını verilen teorik bilgi ile birleştirdiğimizde şu sonuca ulaştık: Işık şiddetini arttırdığımızda, lambadan çıkan ışın miktarı artar, dolayısı ile ışık ölçere gelen ışın miktarı artar yani ışık akısı artar. Işık akısı artarsa, aydınlanma şiddeti artar. Işık ölçer ile lamba arasındaki uzaklık arttığında, cihazın ekranına çarpan ışınların miktarı azalmıştır. Yani, cihazın yüzeyine düşen ışık akısı dolayısı ile yüzeyin aydınlanma şiddeti azalmıştır. Işık ölçerin yüzeyi, lambaya baktığında yani ışık ışınları, ışık ölçerin yüzeyine dik geldiğinden yüzeyin aydınlanma şiddeti en büyük olur, çünkü ışık ölçerin yüzeyine gelen ışın sayısı maksimum olur. Işınların yüzeye gelme açısı arttıkça, hem yüzeye gelen ışın sayısı azalır hem de ışınlar açılı gelmeye başlar. Dolayısı ile yüzeyin aydınlanma şiddeti azalır.

Deney Kutusu

İddia:

Kanıt:

Bu soruyu cevaplamak için ne yaptık?

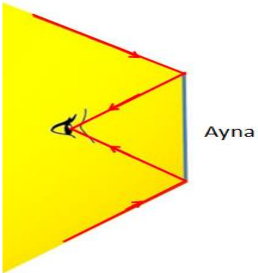
Neden: İddiamız doğrulandı/çürütüldü çünkü…

Sonuç:

Student Handout

Görüş Alanı Çalişma Kağıdi

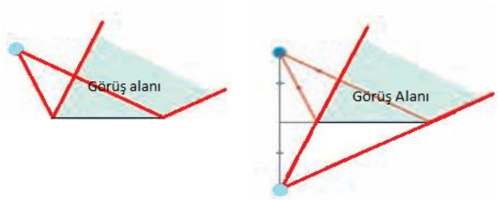
Bir aynada görebildiğimiz alana **görüş alanı** denir. Şekil 1'de sarıya boyalı olarak gösterilen alan, aynaya bakan kişinin görüş alanıdır. Görüş alanında bulunan bütün cisimlerden (eğer arada opak bir engel yok ise) aynaya gelen ışınlar, ayna üzerinden yansır, gözümüze gelir ve görürüz. Görüş alanının sınırlarını, aynanın uçlarından gözümüze gelen ışınlar belirler. Çünkü bu ışınlar, aynadan yansıyarak gözümüze gelen son ışınlardır. Bunlara uç ışın denir. Şekil 1'de kırmızı olarak çizilen ışınlar, görüş alanının sınırlarını belirleyen uç ışınlardır.



Şekil 1. Görüş alanı

Kırmızı ışınların arasındaki sarı bölgedeki ışınlar aynaya gelip, yansıma sonucu gözümüze gelir ve sarı bölgeyi görürüz. Kırmızı ışınlar dışındaki beyaz bölgeden aynaya gelen ışınlar, yansıma sonucu gözümüze gelmez ve beyaz bölgeyi göremeyiz. Kısacası sarı bölge bizim görüş alanımızdır. Görüş alanını bulmak istediğimizde, ilk olarak gözümüze aynanın uç noktalarından geldiğini düşündüğümüz ışınları çizeriz. Ardından bu yansıyan ışınların, aynaya gelen ışınlarını çizeriz.

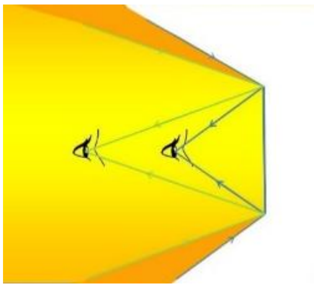
*Kısa yol: Görüş alanını bulmak için en kısa yol, bakan kişinin ayna düzlemine göre simetriğini alıp (çünkü aynaya bakan kişinin görüntüsü, düzlem aynaya göre simetriğidir.), bakan kişinin gözünden aynanın uçlarından geçecek şekilde çizgi çizmektir. Aynanın ön tarafında, çizgiler arasında kalan alan, aynaya bakan kişinin görüş alanıdır (Şekil 2).



Şekil 2. Görüş alanı bulmanın kısa yolu

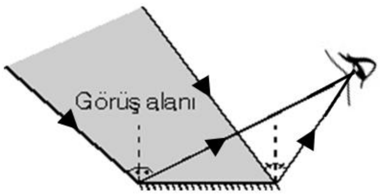
Düzlem ayna önünde ileri-geri hareket ederek ya da sağa-sola hareket ederek ya da aynanın boyutunu değiştirerek görüş alanımızı değiştirebiliriz.

Düzlem aynaya yaklaştığımızda görüş alanımız büyür, çünkü aynaya yaklaştığımızda önceden ayna üzerinden yansıyarak gözümüze ulaşmayan ışınlar (turuncu bölgeden gelen ışınlar), ulaşmaya başlar (Şekil 3). Şekilde aynaya uzak olan gözlemci sadece sarı alanı görebilirken, yaklaştığında sarı alana ek olarak turuncu alanı da görmeye başlar.



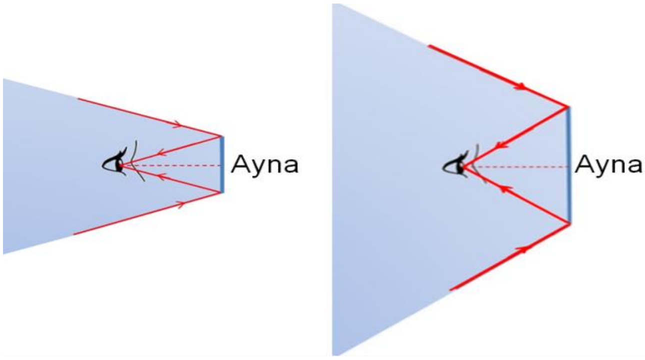
Şekil 3. Farklı uzaklıklardaki gözlemciler için görüş alanı

Düzlem aynanın solundan sağına doğru hareket ettiğimizde sol tarafı, sağından soluna doğru hareket ettiğimizde sağ tarafı görürüz, çünkü biz sağa hareket ettiğimizde, sol taraftan aynaya gelen ışınlar yansıyarak gözümüze ulaşabilirken; biz sola hareket ettiğimizde, sağ taraftan gelen ışınlar yansıyarak gözümüze ulaşabilir (Şekil 4).



Şekil 4. Farklı yönlerdeki gözlemciler için görüş alanı

Düzlem ayna büyüdükçe görüş alanı artar, çünkü ayna küçükken aynaya ulaşamayan ışınlar, aynaya ulaşmaya ve oradan yansıyarak gözümüze ulaşmaya başlar (Şekil 5).



Şekil 5. Farklı boyutlardaki aynalar için görüş alanı

Örnek: Peki, Şekil 1'deki gibi aynaya bakıyor olsaydık, sarı ile boyalı alandaki tüm cisimleri aynaya bakarak görebilir miydik? Neden?

Cevap: Hayır. Görüş alanımızda da olsa, cisimden yansıyan ışınlar gözümüze ulaşmıyorsa o cismi göremeyiz. Örneğin Şekil 6'da aynaya bakan çocuk, hemen arkasında bulunan toz pembe battaniyenin orta kısmını göremez, sadece kenar kısımlarını görür. Görmek için tek şart, battaniyeden yansıyan ışınların, ayna üzerinden yansıyarak çocuğun gözüne gelmesi. Battaniyenin orta kısmından yansıyan ışınların, çocuk tarafından aynaya ulaşması engellenir, dolayısı ile bu ışınlar çocuğun gözüne ulaşamaz. Sonuç olarak orta kısmı göremez.

Şekil 6. Aynaya bakan çocuk

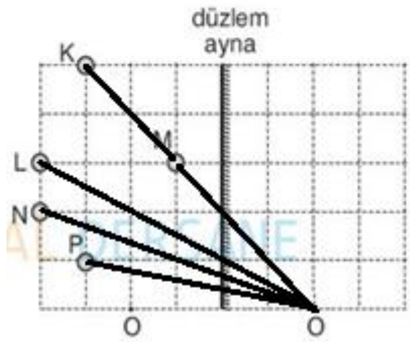
Örnek: (2007 ÖSS)

Düşey kesiti şekildeki gibi olan düzenekte, O noktasından aynaya bakan bir gözlemci düzlem ayna önüne konan K, L, M, N, P çelik bilyelerinden hangisinin görüntüsünü <u>göremez</u>?

A) K B) L C) M D) N E) P

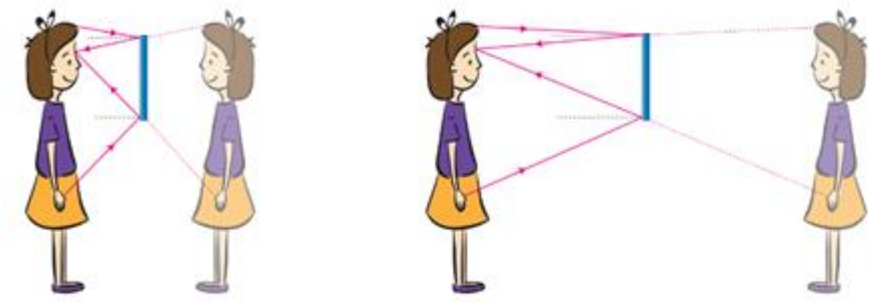
Cevap: K, tüm bilyeler gözlemcinin görüş alanında olmasına rağmen K üzerinden yansıyan ışınlar M cismine çarpar ve aynaya ulaşamaz.

*Kısa yol: O noktasının, düzlem aynaya göre simetriğini alalım. Çünkü O noktasından bakan gözlemcinin aynadan gördüğü görüntü ile, ayna olmadığı durumda O noktasının simetrisinden baktığındaki görüntü aynıdır (Şekil 2'yi hatırlayalım.). O noktasını ve düzlem aynayı yok gibi düşünelim. Gözlemcinin, bilyeleri görebilmesi için, bilyelerden gözlemcinin gözüne ışın gelmelidir. Bu sebeple, bilyelerden, O'nun simetrisine ışın çizelim. L,M,N ve P'den yansıyan ışınlar gözlemciye ulaşırken; K'dan yansıyan ışınlar M bilyesi tarafından engellenir. Gözlemci K'yı göremez.



Örnek: Düzlem aynaya yaklaştığımızda/uzaklaştığımızda, vücudumuzun gördüğümüz bölümü değişir mi?

Cevap: Hayır. Daha iyi anlamak için Şekil 7'yi inceleyelim. Sol taraftaki görselde aynaya yakın duran kız, sağ taraftaki görselde aynaya uzak durmaktadır. İki görselde de uç ışınlar yardımıyla kızın görüş alanını çizersek, başının tepesinden ellerine kadar olan bölgenin görüş alanı içerisinde olduğunu görürürüz. Aynaya olan uzaklığımızı değiştirsekte, vücudumuzun aynada gördüğümüz bölümü her zaman aynıdır.



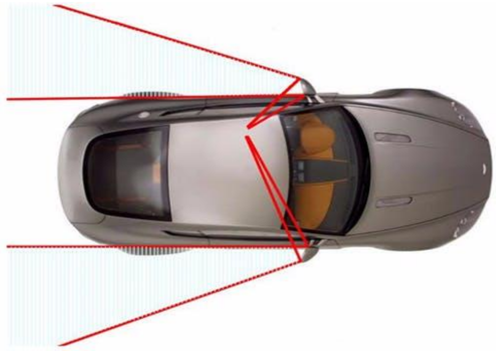
Şekil 7. Aynaya olan uzaklığımızın vücudumuzun gördüğümüz bölümüne etkisi

Soru: Bir başkasına ait arabayı kullanmadan önce koltuğun pozisyonunu ve aynaları kendimize göre ayarlamamız gerekir. Çünkü, bizim boyumuzdan farklı bir boya sahip bir kişinin ayna ayarları bizim için uygun değildir (Şekil 8).

Şekil 8. Sürücü aynaları

Cevap: Koltuğun pozisyonunu ve aynaların yönünü değiştirdiğimizde değişen nedir? Nasıl değişir? Neden? Değişen görüş alanıdır. Aynanın soluna oturduğumuzda, aynayı sağa yönlendirerek, aynadan daha önce göremediğimiz sağ tarafı görebiliriz.

Ya da sol kenarımızdaki dikiz aynasını daha da sola yönlendirdiğimizde, daha önce görmediğimiz sol tarafı görebiliriz. Koltuğumuzu yukarı çıkartarak, aynadan daha önce göremediğimiz alt tarafı görebiliriz. Koltuğu ön tarafa yaklaştırarak, dolayısı ile aynaya yaklaşarak, görüş alanımızı büyütebiliriz. Geri görüşü sağlayan dikiz ve yan aynalara şoför koltuğundan baktığımızda arkamızdaki trafiği sorunsuz bir şekilde görebiliyor olmamız gerekir (Şekil 9). Görüş alanımızı, arkamızdaki trafiği görebilecek şekilde ayarlamalıyız.



Şekil 9. Sürücünün dikiz aynalarından görüş alanları

C. Interview Questions

Pre-Learning Interview Questions

1. Bu ders/çalışma ile ilgili herhangi bir sorunuz var mı?
2. Sizce, fizik nedir?
3. Sizce, öğrenciler/insanlar neden fizik öğrenmeli?
4. Sizce, fizik nasıl öğretilmeli?
5. Öğrencilik hayatınızda (ortaokul/lise/üniversite) fizik dersleriniz vardı. Bu deneyimlerinizi düşündüğünüzde sizde izi kalan bir fizik öğretmeniniz var mı? Hangi fizik öğretmenin neyi iyi/kötü yapıyordu? Nasıl yapmasını önerirsiniz? Neden? Örnek verebilir misin?
6. Fizik öğrenirken **zorluk/sorun** yaşadınız mı? Evet ise, bunlar neydi? Bu zorlukları/sorunları nasıl aştınız? Bu yaşadığın zorluk az önce bahsettiğin öğretmenlerle mi ilgiliydi?
7. Öğrencilik hayatınızda online ders aldınız. Daha önce almış mıydınız? Başarılı bulduğun/ başarısız bulduğun online ders var mıydı? Bu dersin özellikleri nelerdi? Ne iyiydi? Ne kötüydü? Neden? Bu bahsettiğinin öğretmenle ilgisi var mıydı? Ne yapılmasını isterdin? Örnek verebilir misin?
8. Daha önce online derslerde **zorluk/sorun** yaşadınız mı? Evet ise, bunlar neydi? Bu sorunları nasıl aştınız? Bu yaşadığın zorluk az önce bahsettiğin öğretmenlerle mi ilgiliydi? Keşke bu dersi almasaydık, neden bu adam bu dersi veriyor dedirttiği oluyor mu?
9. Öğrencilik hayatınızda (ortaokul/lise/üniversitede) laboratuarda uygulama yaptınız mı? Sizde iz bırakan uygulama (deney) oldu mu (Vaaav dedirten, uff dedirten)? Peki vaaaaw /ufffff demenizin kaynağı nedir (deney, öğretmen, föy vb) Öğretmen neyi iyi yaptğında/ kötü yaptığında hoşuna gidiyordu/gitmiyordu? Nasıl yapılmasını önerirsiniz? Neden? Örnek verebilir misin?

10. Daha önce lab derslerinde **zorluk/sorun** yaşadınız mı? Evet ise, bunlar neydi? Bu zorlukları/sorunları nasıl aştınız
11. Argümantasyon sizce nedir? Sorgulama sizce nedir?
12. Duydunuz mu? Biliyor musunuz? Daha önce argümantasyon deneyiminiz oldu mu? Daha önce inquiry deneyiminiz oldu mu? Bunlarla ilgili ders aldınız mı? Aldığınız derslerin içeriğinde geçti mi? Dersin herhangi bir yerinde geçti mi? Arkadaşlarından alan oldu mu? Nasıldı? Bu deneyimlerinizde **zorluk/sorun** yaşadınız mı? Evet ise, bunlar neydi? Bu sorunları nasıl aştınız?
13. Bu dersten beklentileriniz nelerdir? Bu derste karşılaşmayı beklediğiniz **zorluk/sorun** var mı? Varsa nelerdir? Bu dersin size katkı (bilgi, beceri) sağlayacağını düşünüyor musunuz? Örnek verebilir misiniz?

Post-Learning Interview Questions

1. Sence, fizik nasıl öğretilmeli?
2. Şu ana kadar dersimizle ilgili deneyimin nasıldı?
3. ADI kullanarak işlediğimiz dersimizin <u>beğendiğin</u> yönleri nelerdir? Örnekler vererek nedenini açıklar mısın?
4. ADI kullanarak işlediğimiz dersimizin <u>beğenmediğin</u> ve geliştirilmesi gerektiğini düşündüğün yönleri nelerdir? Örnekler vererek nedenini açıklar mısın?
5. Grupça çalışılıyor olması/Grupların her hafta değişiyor olması/deney süresinin sınırlı olması/bilinçli olarak deneylerde hata yapmanıza izin veriliyor olması senin her hangi bir zorluk/sorun yaşamana sebep oldu mu?
6. Bu deneyimin sana katkı (bilgi ve/veya beceri) sağladığını düşünüyor musun?
    a. Evet ise, bunları örneklendirebilir misin?
    b. Hayır ise, sence sebebini açıklar mısın?
7. Öğrencilik hayatında sen de izi kalan (olumlu ve olumsuz) fizik öğretmenlerini tekrar hatırlamanı istiyorum. Dersin öğretim görevlisi olarak

benim o öğretmenlerinden daha iyi olduğum yönlerim var mıydı? Evet ise örnek verebilir misin?

8. Benim o öğretmenlerle kıyaslandığımda, daha zayıf olduğum noktalar var mıydı? Örnek verebilir misin? Zayıf olduğum noktalarda kendini geliştirmesi açısından neler yapmamı önerirsin? Neden?
9. Bu deneyimini, öğrencilik hayatında sen de izi kalan (olumlu ve olumsuz) (online) dersleri tekrar hatırlamanı istiyorum ile kıyaslayacak olursan, bu ders ile ilgili neler söyleyebilirsin? Bu dersin hangi özelliği/özellikleri diğer (online) derslerden iyidir/kötüdür? Nasıl yapılmasını önerirsin? Neden? Örnek verebilir misin?
10. Bu dersin o derslerden daha iyi olduğunu düşündüğün yönleri var mıydı? Evet ise örnek verebilir misin?
11. Bu dersin o derslerden, daha zayıf olduğu noktalar var mıydı? Örnek verebilir misin? Zayıf olduğu noktaları geliştirmem açısından neler yapmamı önerirsin? Neden?
12. Bu deneyimini, öğrencilik hayatında sen de iz bırakan (olumlu ve olumsuz) laboratuvar dersleri/uygulamalarını tekrar hatırlamanı istiyorum Bu dersin o derslerden daha iyi olduğunu düşündüğün yönleri var mıydı? Evet ise örnek verebilir misin?
13. Bu dersin o derslerden, daha zayıf olduğu noktalar var mıydı? Örnek verebilir misin? Zayıf olduğu noktaları geliştirmem açısından neler yapmamı önerirsin? Neden?
14. Bu dersin şimdiye kadar olan kısmında (learning phase) sende iz bırakan (olumlu ve olumsuz) aktivite/kısım oldu mu? Hangisi? Neden? Nasıl geliştirebilirim?
15. ADI ilgi çekme, keşfetme, argümantasyon 1, açıklama, argümantasyon 2, derinleştirme adımlarından oluşur. ADI'nin adımlarında geliştirmek istediğin bir kısım var mı? Varsa hangisi? Neden? Ya da sıralamada değişiklik yapmayı düşünür müsün? Evet ise, nasıl? Hangi neden(ler)le?

Post-Preparation Interview Questions

1. ADI aktivitesini ve gerekli materyalleri hazırlarken takip ettiğin yolu anlatmanı istiyorum. Materyalleri hazırlarken, hangi çalışmaları yaptın?
2. Her aşama (araştırma, yazma vb) için deneyimin nasıldı? Bu aşamanın beğendiğin yönleri nelerdir? Örnekler vererek nedenini açıklar mısın? Bu aşamada her hangi bir zorluk/sorun yaşadın mı? Evet ise, nelerdir ve neden? Örnek verebilir misin?
3. Bu zorluğu/sorunu aşabildin mi? Evet ise, nasıl aştın? Hayır ise, neden? Çözüm önerin nedir? ADI kullanılarak hazırlanan materyalleri inceledin mi? (Örn: deney föyleri, makalelerde yer alan aktiviteleri, ADI nin kitabını, ADI youtube sayfasını, ADI web sayfasını, benim hazırladığım materyalleri vb)
   a. Evet ise, incelediğin materyallerden faydalandın mı? Ne ölçüde faydalandın? Birebir örnekteki adımları takip ettin mi? Hayır ise neden? Birebir örnekteki içeriği kullandın mı? Hayır ise neden?
   b. Hayır ise, neden?
4. Bu kazanıma ait farklı materyaller (örn: deney föyleri, kitaplar, web sayfaları) inceledin mi?
   a. Evet ise, incelediğin materyallerden faydalandın mı? Ne ölçüde faydalandın? Birebir örneğin aynısını mı kullandın? Hayır ise neden? Faydalandığın materyallerin güvenilir olup olmadığını kontrol ettin mi?
   b. Hayır ise, neden?
5. Ön bilgi yazma ile ilgili deneyiminden bahsedelim. Nasıldı? Örnekler vererek açıklar mısın?
   a. Kazanımınla ilgili ön bilgi verip vermemen ile ilgili bir araştırma yaptın mı?
      i. Evet ise, nerelerden/hangi kaynaklardan faydalandın? (kitap, müfredat, ortaokul müfredatı, websiteleri vb)
      ii. Hayır ise, neden?

b. Bu bölümü hazırlarken her hangi bir zorluk/sorun yaşadın mı? Evet ise, nelerdir ve neden? Örnek verebilir misin? Bu zorluğu/sorunu aşabildin mi? Evet ise, Nasıl aştın? Hayır ise, neden? Çözüm önerin nedir?

6. Kullanacağın bağlamı hazırlama deneyiminden bahsedelim. Nasıldı? Örnekler vererek açıklar mısın?
    a. Kullanacağın bağlam için nerelerden/hangi kaynaklardan faydalandın?
    b. Bağlam seçiminde/yazımında zorluk/sorun yaşadın mı? Evet ise, nelerdir ve neden? Örnek verebilir misin? Bu zorluğu/sorunu aşabildin mi? Evet ise, nasıl aştın? Hayır ise, neden? Çözüm önerin nedir?
    c. Farklı bağlam seçeneklerin vardıysa, neden şimdi kullandığını tercih ettin?
    d. Bağlam soru yazımında zorluk/sorun yaşadın mı? Evet ise, nelerdir ve neden? Örnek verebilir misin? Bu zorluğu/sorunu aşabildin mi? Evet ise, nasıl aştın? Hayır ise, neden? Çözüm önerin nedir?
    e. Bağlam ile kazanımı ilişkilendirme konusunda zorluk/sorun yaşadın mı? Evet ise, nelerdir ve neden? Örnek verebilir misin? Bu zorluğu/sorunu aşabildin mi? Evet ise, nasıl aştın? Hayır ise, neden? Çözüm önerin nedir?
7. Araştırma sorusunu yazma deneyimin nasıldı? Örnekler vererek açıklar mısın?
    a. Araştırma sorusunu yazma/bağlam ile ilişkilendirme konusunda zorluk/sorun yaşadın mı? Evet ise, nelerdir ve neden? Örnek verebilir misin? Bu zorluğu/sorunu aşabildin mi? Evet ise, nasıl aştın? Hayır ise, neden? Çözüm önerin nedir?
    b. Farklı araştırma sorusu seçeneklerin vardıysa, neden şimdi kullandığını tercih ettin?

8. Gelmesi muhtemel iddiaları, kanıtları ve nedenleri yazma (birbirleri ile ilişkilendirme) deneyimine geçelim. Nasıldı?
    a. İddiaları, kanıtları ve nedenleri yazarken bir kaynaktan faydalandın mı yoksa kendin mi yazdın? Faydalandıysan, hangi kaynaklardan faydalandın?
    b. İddia yazımında zorluk/sorun yaşadın mı? Evet ise, nelerdir ve neden? Örnek verebilir misin? Bu zorluğu/sorunu aşabildin mi? Evet ise, nasıl aştın? Hayır ise, neden? Çözüm önerin nedir?
    c. Kanıt yazımında zorluk/sorun yaşadın mı? Evet ise, nelerdir ve neden? Örnek verebilir misin? Bu zorluğu/sorunu aşabildin mi? Evet ise, nasıl aştın? Hayır ise, neden? Çözüm önerin nedir?
    d. Neden yazımında zorluk/sorun yaşadın mı? Evet ise, nelerdir ve neden? Örnek verebilir misin? Bu zorluğu/sorunu aşabildin mi? Evet ise, nasıl aştın? Hayır ise, neden? Çözüm önerin nedir?
    e. İddia, kanıt ve nedenleri ilişkilendirme konusunda zorluk/sorun yaşadın mı? Evet ise, nelerdir ve neden? Örnek verebilir misin? Bu zorluğu/sorunu aşabildin mi? Evet ise, nasıl aştın? Hayır ise, neden? Çözüm önerin nedir?
    f. Öğrencilerden gelebilecek yanlış ihtimalleri (yanlış iddiaları, araştırma sorusunu cevaplamayan iddiaları, sunulabilecek yanlış kanıtları ya da yanlış gerekçeleri vb) göz önünde bulundurdun mu?
        i. Evet ise, nelerdir? Bu durum ile ilgili deneyimin nasıldı? Örnek verebilir misin?
        ii. Hayır ise, neden?
        iii. Yanlış ihtimalleri kurgulama konusunda zorluk/sorun yaşadın mı? Evet ise, nelerdir ve neden? Örnek verebilir misin? Bu zorluğu/sorunu aşabildin mi? Evet ise, nasıl aştın? Hayır ise, neden? Çözüm önerin nedir?
9. Deney (simülasyon/demo) bölümünü hazırlarma aşamasına gelelim. Bu aşama ile ilgili deneyimin nasıldı? Örnekler vererek açıklar mısın?

a. Hangisini (deney/simülasyon/demo) kullanacağına nasıl karar verdin?
b. Kullanacağın deney (simülasyon/demo) için nerelerden/hangi kaynaklardan faydalandın?
c. Bu bölümün yazımında zorluk/sorun yaşadın mı? Evet ise, nelerdir ve neden? Örnek verebilir misin? Bu zorluğu/sorunu aşabildin mi? Evet ise, nasıl aştın? Hayır ise, neden?
d. Farklı deney/simülasyon/demo seçeneklerin vardıysa, neden şimdi kullandığını tercih ettin?
e. Bu deneyi yapan/demoyu yapan/ simülasyonu kullanan öğrencinin, hangi zorlukları/sorunları yaşayabileceğini göz önünde bulundurdun mu?
    i. Evet ise, bu durum ile ilgili deneyimin nasıldı? Örnek verebilir misin? Sence, öğrencin hangi zorlukları/sorunları yaşayabilir? (Simulasyon kullanımı, simulasyon sınırlılıkları, simulasyonda yer alan hatalar, deney sınırlılıkları, güvenlik önlemleri, deney hataları vb.) Belirttiğin zorluğu / sorunu yaşarlarsa nasıl aşabilirsin?
    ii. Hayır ise, neden?
f. Öğrencilerinin yaşayabileceği zorlukları/sorunları kurgulama konusunda zorluk/sorun yaşadın mı? Evet ise, nelerdir ve neden? Örnek verebilir misin? Bu zorluğu/sorunu aşabildin mi? Evet ise, nasıl aştın? Hayır ise, neden? Çözüm önerin nedir?
g. Varsa, deneyin (simülasyonun/demonun) sınırlılıkları nelerdir? Bu sınırlılıkları aşmak için öğretmen materyalinde neler yaptın?
h. Deneyi (simülasyonu/demoyu) denedin mi?
i. Deneyi (simülasyonu/demoyu) ve kazanım ile kolayca ilişkilendirebildin mi?
    i. Hayır ise, neden? Çözüm önerin nedir?

10. Argümantasyon 1 adımını yazma deneyimin nasıl geçti? Örnekler vererek açıklar mısın?

a. Bu bölümün yazımında zorluk/sorun yaşadın mı? Evet ise, nelerdir ve neden? Örnek verebilir misin? Bu zorluğu/sorunu aşabildin mi? Evet ise, nasıl aştın? Hayır ise, neden? Çözüm önerin nedir?

11. Açıklama adımını yazma deneyimin nasıl geçti? Örnekler vererek açıklar mısın?
    a. Bu bölümün yazımında zorluk/sorun yaşadın mı? Evet ise, nelerdir ve neden? Örnek verebilir misin? Bu zorluğu/sorunu aşabildin mi? Evet ise, nasıl aştın? Hayır ise, neden? Çözüm önerin nedir?
    b. Uygun görselleri bulma /açıklama ile ilişkilendirme konusunda zorluk/sorun yaşadın mı? Evet ise, nelerdir ve neden? Örnek verebilir misin? Bu zorluğu/sorunu aşabildin mi? Evet ise, nasıl aştın? Hayır ise, neden? Çözüm önerin nedir?
12. Argümantasyon 2 adımını yazma deneyimin nasıl geçti? Örnekler vererek açıklar mısın?
    a. Bu bölümün yazımında zorluk/sorun yaşadın mı? Evet ise, nelerdir ve neden? Örnek verebilir misin? Bu zorluğu/sorunu aşabildin mi? Evet ise, nasıl aştın? Hayır ise, neden? Çözüm önerin nedir?
    b. Uygun görselleri bulma /nedenler ile ilişkilendirme konusunda zorluk/sorun yaşadın mı? Evet ise, nelerdir ve neden? Örnek verebilir misin? Bu zorluğu/sorunu aşabildin mi? Evet ise, nasıl aştın? Hayır ise, neden? Çözüm önerin nedir?
13. Derinleştirme adımını yazma deneyimin nasıl geçti? Örnekler vererek açıklar mısın?
    a. Bu bölümün yazımında zorluk/sorun yaşadın mı? Evet ise, nelerdir ve neden? Örnek verebilir misin? Bu zorluğu/sorunu aşabildin mi? Evet ise, nasıl aştın? Hayır ise, neden? Çözüm önerin nedir?
    b. Uygun görselleri bulma /sorular ile ilişkilendirme konusunda zorluk/sorun yaşadın mı? Evet ise, nelerdir ve neden? Örnek verebilir misin? Bu zorluğu/sorunu aşabildin mi? Evet ise, nasıl aştın? Hayır ise, neden? Çözüm önerin nedir?

14. Geliştirdiğin materyallerde, öğrencileri yanlış yönlendirebilecek ya da kavram yanılgısına sebep olabilecek noktaları, öğrencilerin sahip olduğu ön-bilgileri göz önünde bulundurdun mu? Evet ise, bu noktalar nelerdir? Hayır ise, neden?
    a. Eğer öğrencileriniz bu noktalarda zorlanırlarsa, bir öğretmen olarak neler yaparsınız?
15. ADI aktivitesi ve gerekli materyalleri hazırlama sürecinin size katkı sağladığını düşünüyor musunuz? Evet ise, nelerdir? (Konuya öğrencinin gözünden bakmak, kavramsal bilgi ve simulasyon (deney) kullanımı, simulasyon (deney) kullanımının bir derse entegre edilmesi vb.)
16. Kendinizi ders anlatmaya yeterli hissediyor musunuz? Hayır ise, neden? Çözüm önerin nedir?

Post (Peer/High School 1/High School 2) Teaching Interview Questions

1. ADI aktivitesiyle kendi arkadaşlarına (lise öğrencilerine) ders anlatmak üzere yapmış olduğun hazırlıktan bahsetmeni istiyorum. Neler yaptın? . Bu deneyimin sana katkıları ne oldu?
    a. Vermiş olduğum dönütlere ilave değişiklikler yaptın mı? Evet ise, bunlar nelerdi? Neden bu ilave değişiklikleri yaptın?
    b. Hazırlık aşamasında olumlu ya da olumsuz sende iz bırakan bir durumla karşılaştın mı?. Evet ise, bunlar nelerdi? Neden ve neden?
    c. Hazırlık aşamasında seni en çok zorlayan şey ne oldu? Bu konuda neden zorlandığını düşünüyorsun? Bu zorluğu nasıl aştın/sorunu nasıl giderdin?Benzer bir hazırlık içerisinde olan başka birine bu zorluğu yaşamaması için neler önerirsin?
2. ADI kullanarak işlediğin ders deneyimin hakkında konuşmak istiyorum. Sence nasıldı? Örnekler vererek açıklar mısın?
    a. Sende olumlu iz bırakan bir durum oldu mu? Evet ise ne(ler) olduğunu ve nedenini açıklar mısın?

b. Olumsuz etkilendiğin durum oldu mu? Evet ise ne(ler) olduğunu ve neden(ler)ini açıklar mısın? Bu durum derste zorluk/sorun yaşamana sebep oldu mu? Evet ise, nasıl bir zorluk yaşadığını anlatır mısın? Hazırlık sürecinde böyle bir zorluk/sorun yaşanabileceğini ve yaşanması durumunda bu süreci nasıl yöneteceğini planlamış mıydın? Bu zorluğu/sorunu aşabildin mi? Evet ise, nasıl? Hayır ise, neden aşamadığını düşünüyorsun? Bir sonraki ders anlatımın için çözüm önerin nedir?
c. Dersin herhangi bir yerinde senden destek isteyen, bazı noktaları anlamadığını belirten, "bunu neden yapıyorum" diyen öğrenci oldu mu? Evet ise, deneyimini anlatır mısın? Hazırlık sürecinde, böyle bir durum yaşanacağını öngörmüş müydün? Evet ise, bu durumun üstesinden gelmeye dair planlama yapmış mıydın? Bu zorluğu/sorunu aşabildin mi? Evet ise, nasıl? Hayır ise, neden? Bir sonraki ders anlatımın için çözüm önerin nedir?
d. Kullandığın görseller yeterli miydi? Uygun muydu? Herhangi bir zorluk/sorun yaşamana sebep oldu mu? Evet ise, bunlar nelerdinelerdir ve neden? Örnek verebilir misin? Daha önceden böyle bir zorluk/sorun yaşanırsa, süreci nasıl yöneteceğini planlamış mıydın? Bu zorluğu/sorunu aşabildin mi? Evet ise, nasıl aştın? Hayır ise, neden? Bir sonraki ders anlatımın için çözüm önerin nedir?
e. Geliştirdiğin materyallerin (Öğretmen materyali, öğrenci çalışma kâğıdı, ADİ adımları deney föyü, ppt) süreci yönetmene etkisi nasıl oldu? Olumlu ya da olumsuz.
f. ADI kullanarak hazırladığın ders anlatımın sırasında herhangi bir aşamasında, bir şeyin eksik olduğunu (örn: malzeme eksikliği, bilgi eksikliği, görsel eksikliği, yönlendirme eksikliği vb.) ve bu eksik olan şey dersime dâhil edilmiş olsaydı gerçekten iyi olurdu diye düşündün mü? Evet ise, nedir ve neden?

g. Bahsettiklerin dışında başka bir zorluk/sorun yaşadın mı? Evet ise, nelerdir ve neden? Örnek verebilir misin? Daha önceden böyle bir zorluk/sorun yaşanırsa, süreci nasıl yöneteceğini planlamış mıydın? Bu zorluğu/sorunu aşabildin mi? Evet ise, nasıl aştın? Hayır ise, neden? Bir sonraki ders anlatımın için çözüm önerin nedir?
h. Öğrencilerin dersin hakkındaki görüşleri sence nasıldı? Neye dayanarak bunu söylüyorsun?

3. Ön bilgi açıklama ile ilgili deneyiminden bahsedelim. Nasıldı? Örnekler vererek açıklar mısın?
    a. Bu bölümü açıklarken her hangi bir zorluk/sorun yaşadın mı? Evet ise, nelerdir ve neden? Örnek verebilir misin? Daha önceden böyle bir zorluk/sorun yaşanırsa, süreci nasıl yöneteceğini planlamış mıydın? Bu zorluğu/sorunu aşabildin mi? Evet ise, nasıl aştın? Hayır ise, neden? Bir sonraki ders anlatımın için çözüm önerin nedir?
4. Bağlamı açıklama deneyiminden bahsedelim. Nasıldı? Örnekler vererek açıklar mısın?
    a. Bağlam açıklamada zorluk/sorun yaşadın mı? Evet ise, nelerdir ve neden? Örnek verebilir misin? Daha önceden böyle bir zorluk/sorun yaşanırsa, süreci nasıl yöneteceğini planlamış mıydın? Bu zorluğu/sorunu aşabildin mi? Evet ise, nasıl aştın? Hayır ise, neden? Bir sonraki ders anlatımın için çözüm önerin nedir?
    b. Bağlamın ilgi çekti mi? Hayır ise, bağlamını değiştirmeyi düşünür müsün? Evet ise, yeni bağlam tercihin nedir? Hayır ise ??
    c. Bağlam sorusunu açıklamada zorluk/sorun yaşadın mı? Evet ise, nelerdir ve neden? Örnek verebilir misin? Hazırlık sürecinde böyle bir zorluk/sorun yaşanabileceğini ve bu durumda süreci nasıl yöneteceğini planlamış mıydın? Bu zorluğu/sorunu aşabildin mi? Evet ise, nasıl aştın? Hayır ise, neden? Bir sonraki ders anlatımın için çözüm önerin nedir?

d. Bağlam sorusunu değiştirmeyi düşünür müsün? Evet ise, yeni bağlam sorusu tercihin ne olur?
e. Bağlam ile kazanımı ilişkilendirme konusunda zorluk/sorun yaşadın mı? Evet ise, nelerdir ve neden? Örnek verebilir misin? Hazırlık sürecinde böyle bir zorluk/sorun yaşanabileceğini ve yaşanması durumunda süreci nasıl yöneteceğini planlamış mıydın? Bu zorluğu/sorunu aşabildin mi? Evet ise, nasıl aştın? Hayır ise, neden? Bir sonraki ders anlatımın için çözüm önerin nedir?
f. Öğrencilerin bağlam ile kazanımı ilişkilendirme konusunda zorluk/sorun yaşadı mı? Evet ise, neden ilişkilendiremediklerini düşünüyorsun? Hazırlık sürecinde du durumun yaşanabileceğini, ve bu durumda ne yapacağını planlamış mıydın? Bu zorluğu/sorunu aşabildin mi? Evet ise, nasıl aştın? Hayır ise, sence neden? Bir sonraki ders anlatımın için çözüm önerin nedir?

5. Araştırma sorusunu açıklama deneyimin nasıldı? Örnekler vererek açıklar mısın?
    a. Araştırma sorusunu açıklama/bağlam ile ilişkilendirme konusunda zorluk/sorun yaşadın mı? Evet ise, nelerdir ve neden? Örnek verebilir misin? Daha önceden böyle bir zorluk/sorun yaşanırsa, süreci nasıl yöneteceğini planlamış mıydın? Bu zorluğu/sorunu aşabildin mi? Evet ise, nasıl aştın? Hayır ise, neden? Bir sonraki ders anlatımın için çözüm önerin nedir?
    b. Öğrencilerin araştırma sorusunu anlama/bağlam ile ilişkilendirme konusunda zorluk/sorun yaşadı mı? Evet ise, nelerdir ve neden? Örnek verebilir misin? Daha önceden böyle bir zorluk/sorun yaşanırsa, süreci nasıl yöneteceğini planlamış mıydın? Bu zorluğu/sorunu aşabildin mi? Evet ise, nasıl aştın? Hayır ise, neden? Bir sonraki ders anlatımın için çözüm önerin nedir?
    c. Araştırma sorunu değiştirmeyi düşünür müsün? Evet ise, yeni araştırma sorusu tercihin nedir?

6. Keşfetme adımı deneyimin nasıldı? Örnekler vererek açıklar mısın?
    a. Öğrencilerinden gelen iddialardan bahseder misin, nasıldı? (Doğru iddia, yanlış iddia, araştırma sorusunu cevaplamayan iddia vb)
    b. Geldiyse, öğrencilerinden gelen yanlış iddia ve araştırma sorusunu cevaplamayan bir iddia öngördüğün bir iddia mıydı? Yanlış iddia ya da araştırma sorusunu cevaplamayan iddia geldiğinde süreci yönetmekte herhangi bir zorluk/sorun yaşadın mı? Evet ise, nelerdir ve neden? Örnek verebilir misin? Daha önceden böyle bir zorluk/sorun yaşanırsa, süreci nasıl yöneteceğini planlamış mıydın? Bu zorluğu/sorunu aşabildin mi? Evet ise, nasıl aştın? Hayır ise, neden? Bir sonraki ders anlatımın için çözüm önerin nedir?
7. Deney/simülasyon/demo aşamasından bahseder misin? Nasıldı?
    a. Kanıt toplama aşamasında herhangi bir zorluk/sorun yaşadın mı? Evet ise, nelerdir ve neden? Örnek verebilir misin? Daha önceden böyle bir zorluk/sorun yaşanırsa, süreci nasıl yöneteceğini planlamış mıydın? Bu zorluğu/sorunu aşabildin mi? Evet ise, nasıl aştın? Hayır ise, neden? Bir sonraki ders anlatımın için çözüm önerin nedir?
    b. Öğrencilerin kanıt toplarken grup olarak mı çalıştı? Evet ise, gruplar kaç kişiden oluşuyordu?
    c. Öğrencilerin iddiaları için kanıt toplarken herhangi bir zorluk/sorun yaşadın mı? Evet ise, nelerdir ve neden? Örnek verebilir misin? Daha önceden böyle bir zorluk/sorun yaşanırsa, süreci nasıl yöneteceğini planlamış mıydın? Bu zorluğu/sorunu aşabildin mi? Evet ise, nasıl aştın? Hayır ise, neden? Bir sonraki ders anlatımın için çözüm önerin nedir?
    d. Deneyi/simülasyonu/demoyu değiştirmeyi düşünür müsün?
8. Argümantasyon 1 adımı deneyimin nasıldı? Örnekler vererek açıklar mısın?
    a. Bu bölümü yönetirken zorluk/sorun yaşadın mı? Evet ise, nelerdir ve neden? Örnek verebilir misin? Daha önceden böyle bir zorluk/sorun yaşanırsa, süreci nasıl yöneteceğini planlamış mıydın? Bu

zorluğu/sorunu aşabildin mi? Evet ise, nasıl aştın? Hayır ise, neden? Bir sonraki ders anlatımın için çözüm önerin nedir?

b. Olduysa, doğru iddialar için toplanan doğru kanıtları tartışırken süreci yönetmekte herhangi bir zorluk/sorun yaşadın mı? Evet ise, nelerdir ve neden? Örnek verebilir misin? Daha önceden böyle bir zorluk/sorun yaşanırsa, süreci nasıl yöneteceğini planlamış mıydın? Bu zorluğu/sorunu aşabildin mi? Evet ise, nasıl aştın? Hayır ise, neden? Bir sonraki ders anlatımın için çözüm önerin nedir?
c. Olduysa, doğru iddialar için toplanan yanlış kanıtları tartışırken süreci yönetmekte herhangi bir zorluk/sorun yaşadın mı? Evet ise, nelerdir ve neden? Örnek verebilir misin? Daha önceden böyle bir zorluk/sorun yaşanırsa, süreci nasıl yöneteceğini planlamış mıydın? Bu zorluğu/sorunu aşabildin mi? Evet ise, nasıl aştın? Hayır ise, neden? Bir sonraki ders anlatımın için çözüm önerin nedir?
d. Geldiyse, yanlış iddia ya da araştırma sorusunu cevaplamayan iddia için toplanan kanıtları tartışırken süreci yönetmekte herhangi bir zorluk/sorun yaşadın mı? Evet ise, nelerdir ve neden? Örnek verebilir misin? Daha önceden böyle bir zorluk/sorun yaşanırsa, süreci nasıl yöneteceğini planlamış mıydın? Bu zorluğu/sorunu aşabildin mi? Evet ise, nasıl aştın? Hayır ise, neden? Bir sonraki ders anlatımın için çözüm önerin nedir?

9. Açıklama adımı deneyimin nasıl geçti? Örnekler vererek açıklar mısın?
   a. Teorik bilgiyi açıklamada zorluk/sorun yaşadın mı? Evet ise, nelerdir ve neden? Örnek verebilir misin? Daha önceden böyle bir zorluk/sorun yaşanırsa, süreci nasıl yöneteceğini planlamış mıydın? Bu zorluğu/sorunu aşabildin mi? Evet ise, nasıl aştın? Hayır ise, neden? Bir sonraki ders anlatımın için çözüm önerin nedir?
   b. Öğrencilerin teorik bilgiyi anlamada zorluk/sorun yaşadın mı? Evet ise, nelerdir ve neden? Örnek verebilir misin? Daha önceden böyle bir zorluk/sorun yaşanırsa, süreci nasıl yöneteceğini planlamış mıydın?

Bu zorluğu/sorunu aşabildin mi? Evet ise, nasıl aştın? Hayır ise, neden? Bir sonraki ders anlatımın için çözüm önerin nedir?

10. Argümantasyon 2 adımı deneyimin nasıl geçti? Örnekler vererek açıklar mısın?
    a. Bu bölümde tartışmayı yönetirken herhangi bir zorluk/sorun yaşadın mı? Evet ise, nelerdir ve neden? Örnek verebilir misin? Daha önceden böyle bir zorluk/sorun yaşanırsa, süreci nasıl yöneteceğini planlamış mıydın? Bu zorluğu/sorunu aşabildin mi? Evet ise, nasıl aştın? Hayır ise, neden? Bir sonraki ders anlatımın için çözüm önerin nedir?
    b. Öğrencilerin iddia, kanıt ve nedenleri ilişkilendirme konusunda zorluk/sorun yaşadı mı? Evet ise, nelerdir ve neden? Örnek verebilir misin? Daha önceden böyle bir zorluk/sorun yaşanırsa, süreci nasıl yöneteceğini planlamış mıydın? Bu zorluğu/sorunu aşabildin mi? Evet ise, nasıl aştın? Hayır ise, neden? Bir sonraki ders anlatımın için çözüm önerin nedir?
11. Derinleştirme adımı deneyimin nasıl geçti? Örnekler vererek açıklar mısın?
    a. Bu bölümde açıklamayı/tartışmayı yönetirken herhangi bir zorluk/sorun yaşadın mı? Evet ise, nelerdir ve neden? Örnek verebilir misin? Daha önceden böyle bir zorluk/sorun yaşanırsa, süreci nasıl yöneteceğini planlamış mıydın? Bu zorluğu/sorunu aşabildin mi? Evet ise, nasıl aştın? Hayır ise, neden? Bir sonraki ders anlatımın için çözüm önerin nedir?
    b. Geliştirdiğin materyallerde, öğrencileri yanlış yönlendirebilecek ya da kavram yanılgısına sebep olabilecek noktalar var mıydı? Evet ise, bu noktalar nelerdir? Bu durum herhangi bir zorluk/sorun yaşamana sebep oldu mu? Evet ise, nelerdir ve neden? Örnek verebilir misin? Daha önceden böyle bir zorluk/sorun yaşanırsa, süreci nasıl yöneteceğini planlamış mıydın? Bu zorluğu/sorunu aşabildin mi? Evet ise, nasıl aştın? Hayır ise, neden? Bir sonraki ders anlatımın için çözüm önerin nedir?

12. Öğrencilerin, hazırladığın deney föylerini sana doldurulmuş olarak ders sonunda gönderdiler. Öğrencilerinin teslim ettikleri föyler beklediğin gibi miydi? Nasıldı?
    a. Deney föylerini değerlendirirken, öğrencilerinin, varsa, karşılaştığı zorlukları/sorunları fark ettin mi? Evet ise, nelerdir? Örnek verebilir misin? Bu zorluğun/sorunun kaynağı ne olabilir? Bir sonraki ders anlatımın için çözüm önerin nedir?
    b. Öğrencilerinin föylerini değerlendirirken herhangi bir zorluk/sorun yaşadın mı? Evet ise, nelerdir ve neden? Örnek verebilir misin? Daha önceden böyle bir zorluk/sorun yaşanırsa, değerlendirmeyi nasıl yapacağını planlamış mıydın? Bu zorluğu/sorunu aşabildin mi? Evet ise, nasıl aştın? Hayır ise, neden? Bir sonraki ders anlatımın için çözüm önerin nedir?
13. Geliştirdiğin ADI aktivitesini arkadaşlarına sunma sürecinin sana katkı sağladığını düşünüyor musun? Evet ise, nelerdir? (gerçek sunumun pilotu olabilir, öğrencilerle yaşayacağım sorunları önceden görmek olabilir, süreci yönetme becerileri (sorgulama, argümantasyon, bilimsel süreç becerileri, bilimsel okuryazarlık, kavramsal anlatım) gelişmiş olabilir.)
14. Kendini, lise öğrencilerine ders anlatmaya yeterli hissediyor musun? Hayır ise, neden? Çözüm önerin nedir?

D. Reflection Guideline

1. **İlgi çekme** adımında yapılanlar:

- Ön bilgi verildi.
- Bağlam kullanıldı.
- Bağlam sorusu soruldu.
- Araştırma sorusu soruldu.

Yukarıda verilen bilgiler göz önünde bulundurulduğunda, **ilgi çekme adımında yapılanlar** hakkındaki görüşleriniz nelerdir? Beğendiğiniz, beğenmediğiniz, anlamakta ve/veya gerçekleştirmekte zorlandığınız veya neden yaptığınızı sorguladığınız.

2. **Keşfetme** adımında yapılanlar:

- İddialar oluşturuldu.
- Deney düzenekleri tasarlandı.
- Deneyler yapıldı.
- Veri toplandı.
- Toplanan veriler kanıt olarak sunuldu.

Yukarıda verilen bilgiler göz önünde bulundurulduğunda, **keşfetme adımında yapılanlar** hakkındaki görüşleriniz nelerdir? Beğendiğiniz, beğenmediğiniz, anlamakta ve/veya gerçekleştirmekte zorlandığınız veya neden yaptığınızı sorguladığınız herhangi bir şey oldu mu? Gerekçeleri ile birlikte açıkça yazınız.

3. **Argümantasyon oturumu 1** adımında yapılanlar:

- Oluşturulan iddialar ve toplanan kanıtlar sınıfla paylaşıldı.
- Başkalarının oluşturduğu iddialar ve kanıtlar öğrenciler tarafından eleştirildi.
- Bilimsel tartışma ortamı yaratıldı.

Yukarıda verilen bilgiler göz önünde bulundurulduğunda, **argümantasyon oturumu 1'de yapılanlar** hakkındaki görüşleriniz nelerdir? Beğendiğiniz, beğenmediğiniz, anlamakta ve/veya gerçekleştirmekte zorlandığınız veya neden yaptığınızı sorguladığınız herhangi bir şey oldu mu? Gerekçeleri ile birlikte açıkça yazınız.

4. **Açıklama** adımında yapılanlar:

- Öğrencilere yaptıkları deneyin altında yatan teorik bilgi öğretim elemanı tarafından verildi.

Yukarıda verilen bilgiler göz önünde bulundurulduğunda, **açıklama adımında yapılanlar** hakkındaki görüşleriniz nelerdir? Beğendiğiniz, beğenmediğiniz, anlamakta ve/veya gerçekleştirmekte zorlandığınız veya neden yaptığınızı sorguladığınız herhangi bir şey oldu mu? Gerekçeleri ile birlikte açıkça yazınız.

5. **Argümantasyon oturumu 2** adımında yapılanlar:

- Öğrencilere gösterdikleri kanıtların, iddialarını neden desteklediği soruldu.
- Bilimsel tartışma ortamı yaratıldı.
- Öğrencilerin gösterdikleri kanıtların, iddialarını neden desteklediği bilgisi öğretmen tarafından verildi.
- Araştırma sorusu cevaplandı.
- Bağlam sorusu cevaplandı.

Yukarıda verilen bilgiler göz önünde bulundurulduğunda, **argümantasyon oturumu 2'de yapılanlar** hakkındaki görüşleriniz nelerdir? Beğendiğiniz, beğenmediğiniz, anlamakta ve/veya gerçekleştirmekte zorlandığınız veya neden yaptığınızı sorguladığınız herhangi bir şey oldu mu? Gerekçeleri ile birlikte açıkça yazınız.

6. **Derinleştirme** adımında yapılanlar:

- Öğrencilere öğrendikleri teorik bilgiyi uygulama fırsatı olarak bir kavramsal soru ve bir ÖSYM sınav sorusu soruldu.

Yukarıda verilen bilgiler göz önünde bulundurulduğunda, **derinleştirme adımında yapılanlar** hakkındaki görüşleriniz nelerdir? Beğendiğiniz, beğenmediğiniz, anlamakta ve/veya gerçekleştirmekte zorlandığınız veya neden yaptığınızı sorguladığınız herhangi bir şey oldu mu? Gerekçeleri ile birlikte açıkça yazınız.

7. ADI aktivitesi sırasında, öğretim elemanının öğretimi ile ilgili beğendiğiniz ve beğenmediğiniz yönlerini ve beğenmediğiniz yönleri hakkında tavsiyelerinizi gerekçeleri ile birlikte açıklayınız.

8. Deney föyü hakkındaki görüşlerinizi (beğendiğiniz ve beğenmediğiniz, varsa anlamakta zorlandığınız yönlerini ve geliştirmek için önerilerinizi) açıklayınız.

9. ADI aktivitesi sırasında herhangi bir noktada kendinize "Bunu neden yapıyorum?" diye sordunuz mu? Cevabınız Evet ise, hangi durumda bu şekilde düşündünüz? Bununla ilgili olarak "öğretim elemanı" ile iletişime geçtiniz mi? Evet ise, sorunuza aldığınız cevap sizi tatmin etti mi?

10. ADI aktivitesi sırasında herhangi bir aşamasında, bir şeyin eksik olduğunu (örn: malzeme eksikliği, bilgi eksikliği, görsel eksikliği, yönlendirme eksikliği vb.) ve bu eksik olan şey ADI aktivitesine dâhil edilmiş olsaydı gerçekten iyi olurdu diye düşündünüz mü? Cevabınız evet ise lütfen açıklayınız.

11. ADI aktivitesi sırasında yukarıda bahsi geçen konular dışında belirtmek istediğiniz herhangi bir şey var ise açıkça belirtiniz?

E. Ethical Approvals

UYGULAMALI ETİK ARAŞTIRMA MERKEZİ
APPLIED ETHICS RESEARCH CENTER

ORTA DOĞU TEKNİK ÜNİVERSİTESİ
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30 OCAK 2019

Konu: Değerlendirme Sonucu

Gönderen: ODTÜ İnsan Araştırmaları Etik Kurulu (İAEK)

İlgi: İnsan Araştırmaları Etik Kurulu Başvurusu

Sayın Doç.Dr. Ömer Faruk ÖZDEMİR

Danışmanlığını yaptığınız Dilber DEMİRTAŞ'ın **"Bağlamsal Argümantasyon Tabanlı Sorgulama ile İşlenen Fizik Derslerinin, Argümantasyon Tabanlı Sorgulama ile İşlenen Fizik Dersleri ile Kıyaslandığında, Çankaya'da 10. Sınıf Öğrencilerin Başarısına, Argümantasyon Becerilerine, Bilimsel Süreç Becerilerine ve Fizik Dersine Karşı Tutumlarına Etkileri Nelerdir?"** başlıklı araştırması İnsan Araştırmaları Etik Kurulu tarafından uygun görülmüş ve **039-ODTÜ-2019** protokol numarası ile onaylanmıştır.

Saygılarımla bilgilerinize sunarım.

Prof. Dr. Tülin GENÇÖZ
Başkan

Prof. Dr. Ayhan SOL
Üye

Prof. Dr. Ayhan Gürbüz DEMİR
Üye

Prof. Dr. Yaşar KONDAKÇI
Üye

Doç. Dr. Emre SELÇUK
Üye

Doç. Dr. Pınar KAYGAN
Üye

Dr. Öğr. Üyesi Ali Emre TURGUT
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ANKARA VALİLİĞİ
Milli Eğitim Müdürlüğü

Sayı : 14588481-605.99-E.4195573 26.02.2019
Konu : Araştırma İzni

ORTA DOĞU TEKNİK ÜNİVERSİTESİ REKTÖRLÜĞÜNE
(Öğrenci İşleri Daire Başkanlığına)

İlgi: a) MEB Yenilik ve Eğitim Teknolojileri Genel Müdürlüğünün 2017/25 nolu Genelgesi.
b) 14.02.2019 Tarihli ve E.96 sayılı yazınız.

Üniversiteniz Ortaöğretim Fen ve Matematik Alanları Eğitimi Anabilim Dalı doktora öğrencisi Dilber DEMİRTAŞ'ın **"Bağlamsal Argümantasyon Tabanlı Sorgulama ile İşlenen Fizik Derslerinin, Argümantasyon Tabanlı Sorgulama İle İşlenen Fizik Dersleri İle Kıyaslandığında Çankaya'da 10.Sınıf Öğrencilerinin Başarısına, Argümantasyon Becerilerine, Bilimsel Süreç Becerilerine ve Fizik Dersine Karşı Tutumlarına Etkileri Nelerdir? "** konulu çalışma kapsamında uygulama talebi Müdürlüğümüzce uygun görülmüş ve uygulamanın yapılacağı İlçe Milli Eğitim Müdürlüklerine bilgi verilmiştir.

Görüşme formunun (46 sayfa) araştırmacı tarafından uygulama yapılacak sayıda çoğaltılması ve çalışmanın bitiminde bir örneğinin (cd ortamında) Müdürlüğümüz Strateji Geliştirme Şubesine gönderilmesini rica ederim.

Turan AKPINAR
Vali a.
Milli Eğitim Müdürü

Adres: Emniyet Mah. Alparslan Türkeş Cad. 4/A
Yenimahalle/ANKARA
Elektronik Ağ: www.meb.gov.tr

a094-68ed-3296-827b-6d71

F. Consent Forms

Gönüllü Katılım Formu

Değerli katılımcı,

Bu çalışma ODTÜ Eğitim Fakültesi, Matematik ve Fen Bilimleri Eğitimi bölümü doktora öğrencisi Dilber DEMİRTAŞ tarafından yürütülmektedir. Çalışmanın amacı, 'Argumantasyon Odaklı Sorgulama (ADI)' modeline göre hazırlanmış fizik dersinin fizik öğretmen adaylarının becerilerine etkilerini araştırmak ve ADI ile fizik öğrenirken/öğretirken öğretmen adaylarının yaşadıkları zorlukları/sorunları ortaya çıkarmaktır. Çalışmanın amacını gerçekleştirebilmek için 10. sınıf optik ünitesinin *Aydınlanma*, *Gölge*, *Yansıma Kanunları*, *Düzlem Aynalar* ve *Görüş Alanı* konuları için içerikler araştırmacı tarafından hazırlanmış; 7 farklı 10. sınıfta pilot çalışması yapılmış ve var olan ölçüm araçları düzenlenmiştir. Bunun için 2020-2021 öğretim yılı güz dönemi içerisinde araştırmacı tarafından geliştirilen içerikle belirlenen konularda ders işlenecektir ve konulara başlamadan ve bittiğinde testler uygulanacaktır. Ardından, katılımcıların ders hazırlaması istenecek ve 3 farklı sınıfta ADI kullanarak aynı konuyu öğretmesi istenecektir. Tüm dönem boyunca düzenli olarak katılımcılar ile mülakatlar yapılacaktır.

Ölçüm araçlarına verdiğiniz cevaplar tamamiyle gizli tutulacak ve sadece araştırmacı tarafından değerlendirilecektir; elde edilecek bilgiler bilimsel yayınlarda kullanılacaktır. İsim ve kimlik bilgileriniz, hiçbir şekilde kimseyle paylaşılmayacaktır.

Geliştirilen içerikler genel olarak kişisel rahatsızlık verecek soruları içermemektedir. Ancak, katılım sırasında herhangi bir nedenden ötürü kendinizi rahatsız hissederseniz herhangi bir aşamada araştırmadan çekilebilirsiniz. Böyle bir durumda araştırmacıya, araştırmayı tamamlayamayacağınızı belirtmeniz yeterli olacaktır.

Çalışma hakkında daha fazla bilgi almak için Dilber DEMİRTAŞ ile iletişim kurabilirsiniz. Çalışmaya sağladığınız katkı için şimdiden çok teşekkür ederim.

Saygılarımla,

Arş. Gör. Dilber Demirtaş
Matematik ve Fen Bilimleri Eğitimi Bölümü
Orta Doğu Teknik Üniversitesi, Ankara

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

Ad Soyad Tarih İmza

CURRICULUM VITAE

PERSONAL INFORMATION

Surname, Name: Demirtaş, Dilber
Nationality: Turkish (TC)

EDUCATION

2011-2024	**Ph.D. After Lisance Programme** Middle East Tecnical University Math. and Science Education Ankara-TÜRKİYE CGPA: 3.71/4.00
2004-2011	**Undergraduate Programme** Middle East Tecnical University Physics Education Ankara-TÜRKİYE CGPA: 3.15/4.00
2000-2004	**High School Programme** Bartın Anatolian Teacher Training High School Bartın-TÜRKİYE CGPA: 5.00/5.00

WORK EXPERIENCE

12.2012-03.2022	**Research Assistance** Middle East Technical University Education Faculty

PROJECTS

03.2016-03.2020	**Physics Teacher and Content Developer** Physics on Stage-Fizik Sahnesi (Middle East Technical University Social Responsibility Project-http://egitimsahnesi.fedu.metu.edu.tr/fizik/)
01.2013-01.2014	**Researcher** Mapping of Misconceptions of High School Physics Students in TÜRKİYE according to Geographic Regions (Middle East Technical University Scientific Research Project – Funding from METU Scientific Research Center)
12.2011-08.2012	**Reseacher and Physics Teacher** Comparison of Effects of Traditional Laboratory Applications and Microcomputer Based Laboratory Applications on 9th and 10th Grade Students' Achievements, Attitudes, Self-efficacies, Scientific Process Skills on the subjects of Mechanics and Electricity. (Ministry of Education Project – Funding from The Scientific and Technological Research Council of TÜRKİYE (TUBITAK)

PROFESSIONAL DEVELOPMENT

09.07.2018-13.07.2018	**Presenter** The Conference of International Research Group on Physics Teaching (GIREP-MPTL) San Sebastian/SPAIN
29.09.2017-30.09.2017	**Workshop Leader** 3rd Bursa Sky Observation Festival Nilüfer National Education Management-Bursa/TÜRKİYE
14.09.2017-16.09.2017	**Presenter** 3rd National Physics Education Congress Gazi University-Ankara/TÜRKİYE
26.08.2017-28.08.2017	**Presenter and Member of Organization Committee** 15th Astronomy Teacher Training Seminars

	Cide National Education Management-Kastamonu/TÜRKİYE
02.02.2017-03.02.2017	**Member of Organization Committe** 13th Astronomy Teacher Training Seminars Middle East Technical University-Ankara/TÜRKİYE
28.09.2016-30.09.2016	**Presenter** 12th National Science and Math. Education Congress Black Sea Technical University-Trabzon/TÜRKİYE
03.06.2016-04.06.2016	**Workshop Leader** 2nd Bursa Sky Observation Festival Yıldırım National Education Management-Bursa/TÜRKİYE
05.12.2015-06.12.2015	**Member of Organization Committe** 5th Astronomy Teacher Training Seminars Middle East Technical University-Ankara/TÜRKİYE
10.09.2015-12.09.2015	**Member of Organization Committe** 2nd National Physics Education Congress Middle East Technical University-Ankara/TÜRKİYE
06.07.2015-10.07.2015	**Presenter** The Conference of International Research Group on Physics Teaching (GIREP) University of Wroclow-Wroclow/POLAND
22.06.2015-26.06.2015	**Participant** 1st International Summer School for Sciences, History and Philosophy of Sciences & Science Education University of Lille-Lille/FRANCE
11.06.2015-14.06.2015	**Workshop Leader** 1st Bursa Sky Observation Festival Yıldırım Governship-Bursa/TÜRKİYE
12.09.2014	**Presenter** 2nd Physics Education without Barriers Workshop Çukurova University-Adana/TÜRKİYE
11.09.2014-14.09.2014	**Presenter** 11nd National Science and Math. Education Congress

Çukurova University-Adana/TÜRKİYE

11.08.2014-15.08.2014	**Lecturer- In-service Physics Teacher Training** Physics Teaching Methods and Techniques Seminar Ministry of Education, Teacher Training and Development General Management-Antalya/TÜRKİYE
14.03.2014-15.03.2014	**Presenter** New Perspectives in Science Education Conference Libreria University-Florance/ITALY
07.08.2013-13.08.2013	**Participant** The 23rd Jyväskylä Summer School- Using Language to Teach Science Jyväskylä University- Jyväskylä/FINLAND
23.04.2013	**Presenter and Member of Organization Committee** 1st Physics Education without Barriers Workshop Middle East Technical University-Ankara/TÜRKİYE
14.03.2013-15.03.2013	**Presenter** New Perspectives in Science Education Conference Libreria University-Florence/ITALY
15.06.2012-28.06.2012	**Participant** Summer Camp-Overseas Education Collage, Chinese Education Xiamen University-Xiamen/CHINA
17.08.2010-28.08.2010	**Participant** Summer School of Utrecht Science and Mathematics Education Utrecht University-Freudental Institute-Utrecht/HOLLAND
04.07.2010-10.07.2010	**Participant** Summer School V on Nuclear Collective Dynamics TUBITAK-Feza Gursey Institute-Istanbul/TÜRKİYE

LANGUAGES

- Turkish(Native)
- English(Fluent)
- Chinese(Intermediate)
- Spanish(Elementary)

COMPUTER LITERACY

- MS Office applications (Excel, Word, Powerpoint, Publisher etc.)(Advanced)
- Windows (Advanced)
- Internet Tools (Advanced)
- Spss 20 (Upper Intermadiate)
- Moodle (Upper Intermadiate)
- Iteman (Intermediate)
- Linux (Intermediate)

SCHOLARSHIPS & AWARDS

- The Scientific and Technological Research Council of TÜRKİYE (TUBITAK) Participation in Abroad Scientific Activities Fellowship / 2015
- The Scientific and Technological Research Council of TÜRKİYE (TUBITAK) Participation in Abroad Scientific Activities Fellowship / 2013
- The best website award-Fidatsu / 2011
- Dean’s High Honor List / 2010-2011 (Spring)
- Dean’s Honor List / 2006-2007 (Fall & Spring), 2007-2008 (Spring)
- ECETAŞ Limited and Industry Company Success Scholarship / 2000-2011
- Turkish Government Scholarship for Higher Education / 2004-2010

INTERESTS

- Astronomy
- Learning Languages
- Swimming
- Drawing and Painting
- Reading books

RESEARCH AREAS

- Physics Education
- Argumentation
- Inquiry Based Learning Approach
- Context Based Approach
- Argument-Driven Inquiry
- Astronomy Education
- Special Education

PUBLICATIONS

BOOKS:

Bülbül, M. Ş., Cansu, Ü., Garip, B., Demirtaş, D. & Eryurt, K. (2013) Herkes için Basit Malzemeler ile Matematik, İğneli Sayfa- Cebir uygulamaları, Ankara: Pegem Akademi.

BOOK CHAPTERS:

Demirtaş, D. (2023). Electric Field. In K. Özmen (Ed.), *Physics Teacher's Solutions Grade 8*. Unlimited Educational Services.

Demirtaş, D. (2023). Electricity. In K. Özmen (Ed.), *Physics Teacher's Solutions Grade 10*. Unlimited Educational Services.

Demirtaş, D. (2023). Electromagnetic Induction. In K. Özmen (Ed.), *Physics Teacher's Solutions Grade 10*. Unlimited Educational Services.

Demirtaş, D. (2023). Electromagnetism. In K. Özmen (Ed.), *Physics Teacher's Solutions Grade 10*. Unlimited Educational Services.

Demirtaş, D. (2023). Electrostatics. In K. Özmen (Ed.), *Physics Teacher's Solutions Grade 8*. Unlimited Educational Services.

Demirtaş, D. (2023). Force. In K. Özmen (Ed.), *Physics Teacher's Solutions Grade 8*. Unlimited Educational Services.

Demirtaş, D. (2023). Lenses. In K. Özmen (Ed.), *Physics Teacher's Solutions Grade 10*. Unlimited Educational Services.

Demirtaş, D. (2023). Light and Shadow. In K. Özmen (Ed.), *Physics Teacher's Solutions Grade 7*. Unlimited Educational Services.

Demirtaş, D. (2023). Magnetism. In K. Özmen (Ed.), *Physics Teacher's Solutions Grade 8*. Unlimited Educational Services.

Demirtaş, D. (2023). Magnetism. In K. Özmen (Ed.), *Physics Teacher's Solutions Grade 9*. Unlimited Educational Services.

Demirtaş, D. (2023). Magnets. In K. Özmen (Ed.), *Physics Teacher's Solutions Grade 10*. Unlimited Educational Services.

Demirtaş, D. (2023). Mechanical Properties of Matter. In K. Özmen (Ed.), *Physics Teacher's Solutions Grade 12*. Unlimited Educational Services.

Demirtaş, D. (2023). Momentum and Impulse. In K. Özmen (Ed.), *Physics Teacher's Solutions Grade 11*. Unlimited Educational Services.

Demirtaş, D. (2023). Newton's Law of Motion. In K. Özmen (Ed.), *Physics Teacher's Solutions Grade 11*. Unlimited Educational Services.

Demirtaş, D. (2023). Pressure. In K. Özmen (Ed.), *Physics Teacher's Solutions Grade 7*. Unlimited Educational Services.

Demirtaş, D. (2023). Reflection of Light. In K. Özmen (Ed.), *Physics Teacher's Solutiıns Grade 7*. Unlimited Educational Services.

Demirtaş, D. (2023). Refraction of Light. In K. Özmen (Ed.), *Physics Teacher's Solutions Grade 10*. Unlimited Educational Services.

Demirtaş, D. (2023). Resistors. In K. Özmen (Ed.), *Physics Teacher's Solutions Grade 10*. Unlimited Educational Services.

Demirtaş, D. (2023). Sound Waves. In K. Özmen (Ed.), *Physics Teacher's Solutions Grade 9*. Unlimited Educational Services.

Demirtaş, D. (2023). Thermal Properties of Matter. In K. Özmen (Ed.), *Physics Teacher's Solutions Grade 12*. Unlimited Educational Services.

Demirtaş, D. (2023). Waves. In K. Özmen (Ed.), *Physics Teacher's Solutions Grade 9*. Unlimited Educational Services.

Demirtaş, D. (2023). Work and Energy. In K. Özmen (Ed.), *Physics Teacher's Solutions Grade 7*. Unlimited Educational Services.

Demirtaş, D. (2023). Work, Energy and Power. In K. Özmen (Ed.), *Physics Teacher's Solutions Grade 11*. Unlimited Educational Services.

Akgümüş, İ., & Demirtaş, D. (2022). Sound Waves. In K. Özmen (Ed.), *Physics Grade 9*. Unlimited Educational Services.

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Demirtaş, D. (2022). Electricity. In K. Özmen (Ed.), *Physics Teacher's Solutions Grade 9*. Unlimited Educational Services.

Demirtaş, D. (2022). Electromagnetic Induction. In K. Özmen (Ed.), *Physics Grade 10*. Unlimited Educational Services.

Demirtaş, D. (2022). Electrostatics. In K. Özmen (Ed.), *Physics Grade 8*. Unlimited Educational Services.

Demirtaş, D. (2022). Magnetism. In K. Özmen (Ed.), *Physics Grade 9*. Unlimited Educational Services.

Demirtaş, D. (2022). Pressure. In K. Özmen (Ed.), *Physics Grade 7*. Unlimited Educational Services.

Demirtaş, D. (2022). Work and Energy. In K. Özmen (Ed.), *Physics Grade 7*. Unlimited Educational Services.

Demirtaş, D., & Akgümüş, İ. (2022). Light and Shadow. In K. Özmen (Ed.), *Physics Grade 7*. Unlimited Educational Services.

Demirtaş, D., & Akgümüş, İ. (2022). Reflection of Light. In K. Özmen (Ed.), *Physics Grade 7*. Unlimited Educational Services.

Toprak, T., & Demirtaş, D. (2022). Electric Current. In K. Özmen (Ed.), *Physics Grade 9*. Unlimited Educational Services.

Toprak, T., & Demirtaş, D. (2022). Electricity. In K. Özmen (Ed.), *Physics Grade 10*. Unlimited Educational Services.

ARTICLE:

Bülbül, M. Ş., Garip, B., Cansu, Ü. & Demirtaş, D., (2012). Mathematics instructional materials designed for blinds: Needle page. *İlköğretim-Online Dergisi*, ISSN: 1305-3515.

PROCEEDINGS:

Demirtaş, D., Yıldırım (2018). Preservice Physics Teachers' Challanges in Implementing Context-Based Argument Driven Inquiry (CADI) Activities. *The GIREP-EPEC Conference*: Wroclaw.

Eryılmaz, A., Garip, B., Demirtaş, D., Özdemir, Ö.F., Yıldırım (2017). ÖĞRETMENLERİN KALİTELİ MATERYAL İHTİYACINA BİR ÇÖZÜM: ODTÜ FİZİK SAHNESİ ÖRNEĞİ. 3. Ulusal Fizik Eğitimi Kongresi, (p. 82). Ankara. Rerieved from http://ufek.gazi.edu.tr/docs/UFEK2017_Ozetler/mobile/index.html#p=94

Eryılmaz, A., Özdemir, Ö.F., Yıldırım, U., Eraslan, F., Eryurt, K., Garip, B., Demirtaş, D. (2016). TÜRKİYE'DE LİSE ÖĞRENCİLERİNİN FİZİK KONULARINDAKİ KAVRAM YANILGILARININ COĞRAFİK BÖLGELERE GÖRE HARİTALANMASI. 12. Ulusal Fen Bilimleri Ve Matematik Eğitimi Kongresi, (p. 280). Ankara. Retrieved from http://www.ufbmek.org/wp-content/uploads/2016/10/Bildiri-%C3%96zet-Kitap%C3%A7%C4%B1%C4%9F%C4%B1.pdf

Eryılmaz, A., Özdemir, Ö.F., Yıldırım, U., Eraslan, F., Eryurt, K., Garip, B., Demirtaş, D. (2016). LİSE ÖĞRENCİLERİNİN KUVVET VE HAREKET KONUSUNDAKİ KAVRAM YANILGILARI VE KİNEMATİK GRAFİKLERİNİ ANLAMA KONUSUNDA YAŞADIĞI ZORLUKLAR. 12. Ulusal Fen Bilimleri Ve Matematik Eğitimi Kongresi, (p. 281). Ankara. Retrieved from http://www.ufbmek.org/wp-content/uploads/2016/10/Bildiri-%C3%96zet-Kitap%C3%A7%C4%B1%C4%9F%C4%B1.pdf

Eryılmaz, A., Özdemir, Ö.F., Yıldırım, U., Eraslan, F., Eryurt, K., Garip, B., Demirtaş, D. (2016). LİSE ÖĞRENCİLERİNİN BASİT ELEKTRİK DEVRELERİ VE GEOMETRİK OPTİK KONUSUNDAKİ KAVRAM YANILGILARI. 12. Ulusal Fen Bilimleri Ve Matematik Eğitimi Kongresi, (p. 281). Ankara. Retrieved from http://www.ufbmek.org/wp-content/uploads/2016/10/Bildiri-%C3%96zet-Kitap%C3%A7%C4%B1%C4%9F%C4%B1.pdf

Eryılmaz, A., Özdemir, Ö.F., Yıldırım, U., Eraslan, F., Eryurt, K., Garip, B., Demirtaş, D. (2016). LİSE ÖĞRENCİLERİNİN YEDİ COĞRAFİK

BÖLGEYE GÖRE KAVRAM YANILGILARI DAĞILIMI VE ÖĞRENCİLERİN KAVRAM YANILGILARI ARASINDAKİ İLİŞKİ ANALİZİ. 12. Ulusal Fen Bilimleri Ve Matematik Eğitimi Kongresi, (p. 282). Ankara. Retrieved from http://www.ufbmek.org/wp-content/uploads/2016/10/Bildiri-%C3%96zet-Kitap%C3%A7%C4%B1%C4%9F%C4%B1.pdf

Yıldırım, U., Eryurt, K., Demirtaş, D., Garip, B. (2015).Relationship between Pre-service Physics Teachers FCI Performance and Their Feedback on FCI Results. *The GIREP-EPEC Conference*: Wroclaw.

Bülbül, M.Ş., Garip, B., Demirtaş, D., Eryurt, K. . (2014). Engelsiz Fizik Eğitim Çalıştayı: Yeniden Canlandırma Uygulamaları. *12. Ulusal Fen Bilimleri ve Matematik Eğitimi Kongresi*, (p. 728). Adana.

Garip, B., Özpolat, E., Demirtaş, D. & Bülbül, M.Ş. (2014). Schools for All. *New Perspectives in Science Education Conference.* Libreria Universitaria. Retrieved from https://conference.pixel-online.net/NPSE/files/npse/ed0003/FP/0191-SEDP156-FP-NPSE3.pdf

Bulbul, M. S., Demirtaş, D., Garip, B. & Oktay, O. (2013). Re-simulating": physics simulations for blind students. *New Perspectives in Science Education Conference*. Libreria Universitaria. Retrieved from http://conference.pixel-online.net/npse2013/common/download/Paper_pdf/292-SDP02-FP-Bulbul-NPSE2013.pdf

Bulbul, M. S., Garip, B., & Demirtaş, D. (2013). Testing context based, self learning material with a blind student: a wisdom box. *New Perspective in Science Education Conference*. Libreria Universitaria. Retrieved from http://conference.pixel-online.net/npse2013/common/download/Paper_pdf/296-SDP03-FP-Bulbul-NPSE2013.pdf

Bülbül, M. Ş., Cansu, Ü., Demirtaş, D., & Garip, B. (2012). İğneli sayfa ile görme engellilerin kullandığı diğer matematik öğrenme setlerinin karşılaştırılması. *X. Ulusal Fen Bilimleri ve Matematik Eğitimi Kongresi* (p. 434).

Bülbül, M. Ş., Demirtaş, D., Cansu, Ü., Oktay, Ö. & Garip, B. (2012). Views and Recommendations about 9th Grade Force and Motion Unit From Physics Teachers who studied with Visually Impaired Students. *Applied Education Congress* (s. 220-221). Ankara: Metu.

REFERENCES

- Prof. Dr. Ali ERYILMAZ, Mathamatics and Science Education Department, Middle East Technical University

- Doç. Dr. Ömer Faruk ÖZDEMİR, Mathamatics and Science Education Department, Middle East Technical University

- Instructor, Dr. Ufuk YILDIRIM, Mathematics and Science Education Department, Middle East Technical University

- General Manager Assistant, Hande Çetin, Unlimited Educational Services