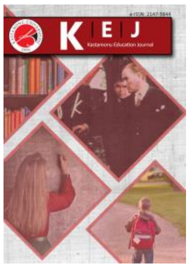
Kastamonu Education Journal, 2024, Vol. 32, No:2, 201-214
doi: 10.24106/kefdergi.1473470



| Research Article / Araştırma Makalesi |

Shedding Light on Pre-Service Science Teachers' Instructional Preferences and Hurdles in Teaching Phases of the Moon

Öğretmen Adaylarının Ay'ın Evreleri Konusundaki Öğretim Tercihleri ve Karşılaştıkları Zorluklara Işık Tutmak

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Keywords

1. Moon's phases
2. Pre-service science teachers
3. Knowledge of instruction

Anahtar Kelimeler

1. Ayın evreleri
2. Fen bilgisi öğretmen adayları
3. Öğretim bilgisi

Received/Başvuru Tarihi
25.04.2023

Accepted / Kabul Tarihi
12.03.2024

Abstract

Purpose: This study aimed to investigate the instructional methods employed by pre-service science teachers and explore the difficulties they encountered while teaching the concept of moon phases.

Design/Methodology/Approach: The present study employed a qualitative research approach using case study methodology to explore the experiences of eight pre-service science teachers. Data were collected through observation of instruction, examination of lesson plans, and semi-structured interviews to gain insights into their instructional practices and challenges. Specifically, the study aimed to understand the difficulties encountered by these pre-service teachers when teaching the phases of the moon. This approach allowed for a rich and in-depth understanding of the complex nature of teaching science to pre-service teachers.

Findings: Analysis revealed that pre-service science teachers predominantly favored physical models and simulations for teaching moon phases. However, the study also identified challenges faced by these teachers in implementing topic-specific teaching strategies.

Highlights: These issues highlight the importance of equipping pre-service science teachers with adequate preparation and resources to effectively teach the phases of the moon. Addressing these concerns may involve providing accurate models, instructing on proper terminology, and offering activities that foster spatial awareness to enhance their understanding and teaching abilities.

Öz

Çalışmanın amacı: Bu çalışma, fen bilgisi öğretmen adaylarının ayın evreleri kavramının öğretiminde kullandıkları öğretim yöntemlerini araştırmayı ve karşılaştıkları zorlukları keşfetmeyi amaçlamıştır.

Materyal ve Yöntem: Mevcut çalışmada sekiz fen bilgisi öğretmeni adayının deneyimlerini keşfetmek için vaka çalışması yöntemini kullanan nitel bir araştırma yaklaşımı kullanmıştır. Veriler, öğretim uygulamaları ve zorlukları hakkında fikir edinmek için öğretimin gözlemlenmesi, ders planlarının incelenmesi ve yarı yapılandırılmış görüşmeler yoluyla toplanmıştır. Çalışma özellikle bu öğretmen adaylarının ayın evrelerini öğretirken karşılaştıkları zorlukları anlamayı amaçlamıştır. Bu yaklaşım, öğretmen adaylarına fen bilgisi öğretmenin karmaşık doğasının zengin ve derinlemesine anlaşılmasını sağlamıştır.

Bulgular: Yapılan analizlerde fen bilgisi öğretmen adaylarının ağırlıklı olarak ayın evrelerini öğretmek için fiziksel modelleri ve simülasyonları tercih ettiğini tespit edilmiştir. Ancak, öğretmen adaylarının konuya özgü öğretim stratejilerini uygulamada zorluklarla karşılaştıkları da görülmüştür.

Önemli Vurgular: Bu bulgular, ayın evrelerini etkili bir şekilde öğretmek için fen bilimleri öğretmen adaylarını yeterli hazırlık ve kaynaklarla donatmanın önemini vurgulamaktadır. Öğretmen adaylarına doğru modeller sağlamak, uygun terminoloji konusunda bilgi vermek, uzamsal yeteneklerini artıracak aktiviteler sunmak gibi öğeleri içermelidir.

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Citation/Alıntı: Sagdıç, A. (2024). Shedding Light on Pre-Service Science Teachers' Instructional Preferences and Hurdles in Teaching Phases of the Moon, *Kastamonu Education Journal, 32*(2), 201-214. doi: 10.24106/kefdergi.1473470

INTRODUCTION

Our knowledge of how we observe the moon with its different phases is one of the oldest pieces of information considering the history of science. It was recorded that Anaxagoras proposed the first scientific explanation of the moon's phases in the fifth century BC (Heath, 1931, as cited in Subramaniam & Padalkar, 2009). In other words, we have known the reasons behind observing different moon phases for over 2500 years. However, comprehending why we observe different shapes of the moon from Earth remains a challenging phenomenon for both students and adults. From the initial research conducted in the 1950s to the present, numerous studies have revealed a deficiency in understanding moon phases (Cohen & Kagan, 1979; Haupt, 1950; Jones & Lynch, 1987). The reasons for this are generally attributed to deficiencies in observations required to comprehend the complex systems among the sun, Earth, and moon (Gazit et al., 2005), teachers' insufficient conceptual understanding, and shortcomings in teacher education programs (Hemenway, 2009), as well as individual's lack of spatial reasoning abilities (Black, 2005; Cole et al., 2015; Wilhelm, 2009). Various teaching methods and techniques have been tested to address these issues and enhance individuals' understanding of the moon's phases. While instructing, multiple instructional strategies are often employed concurrently. For instance, students may observe the moon's phases with the naked eye, record their observations, discuss patterns detected through observation, and develop a model to explain the moon's phases (Abell et al., 2002; Ogan-Bekiroglu, 2007). Moreover, studies have focused on employing group discussion, drawing, and the presentation of three-dimensional models as additional teaching methods (Wilhelm et al., 2007).

Results of previous studies have shown that model-based education (Galperin & Raviolo, 2019), simulations (Kiroğlu et al., 2021; Ucar, 2014), planetariums (Hobson et al., 2010), visual representations (Parnafes, 2012), group discussions (Abell et al., 2001), didactic games (Susman & Pavlin, 2020) and historical moon stories (Abell et al., 2002) are effective methods for teaching phases of the moon. Given the existing literature, it is reasonable to assert that we understand the factors that inhibit the comprehension of lunar phases and how to address these deficiencies. However, there is limited knowledge about pre-service science teachers' instructional capabilities and the challenges they face while teaching about the moon's phases. Consequently, this study focuses on examining senior pre-service science teachers' instruction on the moon's phases. Identifying pre-service science teachers' instructional approaches is significant, as it provides insight into the future teachers' methods of teaching lunar phases. The primary objective of this study is to identify the obstacles encountered by pre-service science teachers while instructing on the moon's phases.

Examining teachers' instructional knowledge of the moon's phases is not only worthwhile but also essential, given the complexity of the concept. To capture students' interest and facilitate their understanding, pre-service science teachers must possess the necessary teaching skills to effectively convey such a challenging topic. The way pre-service teachers employ their knowledge in teaching practice is a clear indicator of their potential success in engaging students. Consequently, this study focuses on exploring pedagogical content knowledge to uncover potential shortcomings in their instruction. The findings of the current study will be beneficial for teacher educators in enhancing the quality of teacher training programs, ensuring that future science teachers are better equipped to teach complex concepts, such as the moon's phases, to their students.

Research questions

1.) What are the pre-service science teachers' instructional knowledge on phases of the moon?

2.) How do pre-service science teachers instruct on phases of the moon?

3.) In what ways do the challenges experienced by Pre-Service Teachers when teaching phases of the moon?

This study was conducted to investigate the challenges that pre-service science teachers experienced while instructing on phases of the moon. Regrettably, previous research on astronomy education has primarily focused on teachers' conceptual understanding difficulties, overlooking potential issues that may arise during instruction on lunar phases. It is reasonable to assume that, given the complexity of conceptualizing moon phases, pre-service science teachers may face challenges while teaching this subject. To effectively teach the moon's phases, teachers should possess sophisticated instructional knowledge and be equipped with a repertoire of appropriate techniques and methods that address students' difficulties (Broadfoot & Ginns, 2009; Marks, 1990; Shulman, 1987). Throughout their teacher education, pre-service science teachers acquire proficiency in diverse teaching methodologies and approaches, yet exceptional educators are frequently characterized by their content-specific pedagogical expertise (Geddis, 1993). The decisions teachers make in selecting and implementing teaching strategies can either facilitate or hinder students' understanding of lunar phases. Consequently, the current study examined pre-service science teachers' knowledge of topic-specific instructional strategies for teaching the moon's phases. By identifying areas of improvement, this research aims to contribute to the development of more engaging and effective instructional approaches that will ultimately enhance students' comprehension of this fascinating yet complex subject.

Teaching phases of the moon

Astronomy topics are an integral part of the science education curricula worldwide. Curriculum developers from various countries incorporate astronomy issues into their science education programs, recognizing the benefits of teaching astronomy (Bailey & Slater, 2004; Pasachoff & Percy, 2009). Consequently, teaching astronomy, including moon phases, provides practical advantages for students. Astronomy issues serve as a context for teaching concepts in physics and mathematics. To cite an example, heat and energy concepts can be introduced through climate discussions, while Earth's interior heat and gravity concepts may be taught using tides and Kepler's laws (Plotnick et al., 2009). Additionally, astronomy fosters connections with mathematics and enhances students' attitudes towards the subject (Ros, 2009). Trigonometry, logarithms, and calculus can be taught through astronomy topics. Moreover, astronomy serves as an effective vehicle for teaching the history of science and the nature of science (Percy, 2009). Students may observe and record the moon's phases, reflecting the empirical nature of science. They may also share their explanations of the moon's phases, demonstrating the socially embedded nature of science (Abell et al., 2001). Furthermore, historical moon stories depicting perspectives from ancient Egypt, China, India, and Greece can be used to help students understand the tentative nature of science (Abell et al., 2002).

While astronomy topics offer numerous advantages, teachers often face challenges when instructing students on the moon's phases. These complex concepts can be difficult to explain, and various obstacles hinder effective teaching and learning. The inherent nature of astronomy contributes to these difficulties (Pasachoff & Percy, 2009). Teaching astronomy through hands-on activities often necessitates students being outdoors at night. Since stars and many planets are primarily visible during nighttime hours, providing suitable conditions for student observation presents a significant challenge for educators. Moreover, although telescopes are essential tools for astronomy, schools and families may lack the financial resources to acquire them in many situations. Spatial reasoning abilities are also critical for understanding the moon's phases adequately. Studies (e.g., Cole et al., 2015) have reported that low spatial abilities impede comprehension of lunar phases. To grasp the moon's phases, individuals must switch their reference points between Earth and space perspectives (Plummer, 2014), and mentally visualize and rotate the sun-Earth-moon system (Wilhelm et al., 2013).

Research findings (e.g., Chastenay, 2016; Ucar, 2014) showed that understanding moon phases is not an easy task. Therefore, teachers must transform this topic into more accessible forms for their students. In other words, teachers should convert their knowledge into teachable formats for teaching moon phases. In the literature, these characteristics are referred to as pedagogical content knowledge. The term "pedagogical content knowledge" was introduced by Shulman (1987) and identified as a unique form of teachers' professional knowledge encompassing both pedagogy and content. Teachers make a subject more comprehensible and intelligible for others through pedagogical content knowledge (Shulman, 1986). In other words, pedagogical content knowledge refers to teachers' reorganization of subject matter and related components, considering the abilities and characteristics of learners for instruction (Magnusson et al., 2006). Pedagogical content knowledge consists of the knowledge of curriculum, students' difficulties, assessment, and instructional strategies (Tamir, 1988). One component of pedagogical content knowledge is the knowledge of instructional strategies, including subject-specific and topic-specific strategies (Magnusson et al., 2006). Subject-specific refers to general approaches to teaching science topics, while topic-specific instructional strategy corresponds to specific activities and representations related to a particular science topic. By honing their pedagogical content knowledge, teachers can more effectively present complex subjects like moon phases to their students. This, in turn, can help facilitate deeper understanding and appreciation for the topic, ultimately contributing to a more enriching educational experience.

In literature, few studies investigate in-service or pre-service teachers' knowledge of instruction regarding astronomy topics. One study found that urban school teachers prefer class discussions as a primary teaching method, while employing laboratory experiments and simulations for astronomy instruction (Miranda, 2010). Similarly, teachers regarded experiments and observations (Kahraman, 2006), 6-sigma method (Sontay & Karamustafaoğlu, 2019) as the effective methods for teaching astronomy content. In a more recent study conducted by Tascan and Unal (2020), teachers reported employing videos and animations, and models in the instruction of lunar related topics. In the same study, Merve and Unal emphasized that methodologies employed by teachers exhibit a considerable degree of uniformity, potentially indicating inadequacy in realizing the targeted educational objectives. In addition to studies conducted with in-service teachers, Lee (2011) examined pre-service elementary teachers' perceptions of their ability to teach the topic of moon phases. Pre-service science teachers participated in inquiry-based instruction to learn about moon phases and then discussed patterns and reasons for moon phases with elementary students via an internet messaging system. Lee reached the conclusion that pre-service science teachers perceived an improvement in their abilities to instruct on moon phases. In light of earlier research, it becomes apparent that there has been limited study into the instructional practices of teachers or teacher candidates. These studies generally focus on astronomy subjects and subject-specific strategies rather than topic-specific strategies for moon phases. In summary, the present study aims to examine pre-service science teachers' specific knowledge of instruction regarding moon phases. We also intend to highlight the challenges pre-service science teachers face while instructing on moon phases.

METHOD

Research design

This investigation employed a qualitative approach using case study design, which involves examining one or more cases to gain a comprehensive understanding of a subject matter (Creswell, 2007). Case studies explore various aspects of a real-life setting and provide an in-depth insight into the issue at hand within predetermined boundaries, considering the whole context (Merriam, 2009). This method aims to offer a holistic view of the topic under study (Stake, 2005). Upon careful consideration, the case study was determined to be the most appropriate approach for identifying pre-service science teachers' instructional preferences and the challenges they encountered. Furthermore, by employing a case study approach, we were able to conduct a thorough analysis of the pre-service science teachers' instruction, interviews, and lesson plans of the participants, which served as valuable data sources for our research. Incorporating multiple data sources in case studies is essential for enhancing the credibility of the findings (Yin, 2003).

Participants and setting

The study was conducted in the fall semester of the academic year 2022-2023 at a public university, and the process of collecting data extended over a period of four months. The participants in the current study were eight pre-service science teachers enrolled in a "school experience" course. This course aimed to provide opportunities for pre-service teachers to instruct their classmates and middle school students, as well as observe and evaluate instruction on various science topics. Accordingly, the pre-service teachers delivered instruction at middle school and during class meetings. In response to feasibility concerns, the study's focus was refined to exclusively examine phases of the moon instruction within the context of class meetings. During these sessions, eight pre-service science teachers voluntarily engaged in microteaching, delivering instruction on lunar phases to their classmates. Importantly, this study solely concentrated on the instructional interactions among pre-service science teachers themselves, rather than extending to middle school students. It is also noteworthy that pre-service teachers had no prior experience teaching moon phases and had completed a one-semester astronomy course covering basic principles. Pseudonyms were assigned to the participants of the study to ensure anonymity and maintain confidentiality throughout the research process.

The study's currentness is noteworthy as it provides valuable insights into the phases of the moon, a topic that still remains integral to the subject matter of science education. Since the challenges in comprehending and instructing the phases of the moon stem from its inherent complexity, researchers should continually explore innovative pedagogical approaches and assess the effectiveness of the current techniques.

Data sources

Instruction: The primary data sources for the present study were the instructional sessions conducted by pre-service science teachers on the topic of moon's phases. The pre-service science teachers were instructed to teach their classmates the concepts of moon phases, using any teaching methodology or technique of their choice. The instruction sessions were recorded on video and lasted approximately forty minutes each. The videotaped sessions were analyzed to extract relevant data for the study. Moreover, the pre-service science teachers were provided with a format for the lesson plan, and they were asked to explain the details of their instruction. The researcher of the current study provided guidance on how to prepare lesson plans, which included four main parts: the intention or objectives of the instruction, difficulties and limitations connected with teaching phases of the moon, teaching procedures, including the rationale for using specific techniques and instructional materials, and evaluation.

In addition to the instructional sessions and lesson plans, semi-structured interviews were employed as supplementary data sources to provide a more comprehensive understanding of the pre-service science teachers' knowledge and instructional strategies related to phases of the moon. Specifically, semi-structured interviews were conducted after the instructional sessions to explore the teachers' topic-specific instructional knowledge. The interview questions aimed to elicit information about the teachers' preparation for instructing on phases of the moon, their rationale for choosing specific teaching methods, their knowledge of alternative methods, their understanding of the sun/moon/earth system, and their reflections on how to improve their instruction. The interview questions were presented in Table 1.

Table 1. Interview questions

Questions
How did you prepare for instructing on phases of the moon?
Why did you choose …… method for your instruction?
What are the alternatives methods for instructing on phases of the moon?
To what extent do your models reflect the nature of the sun/moon/earth system?
How would you improve your instruction if you taught it again?

Data analysis

The data sources for this study, including instructional records, interview transcripts, and lesson plans, were analyzed using qualitative methods. A holistic approach was adopted to ensure that all relevant information was considered during the analysis. The study drew inferences from the pre-service science teachers' instruction, their lesson plans, and their responses to the interview questions. To obtain accurate interpretations regarding the obstacles that pre-service science teachers face and their preferences for instructional strategies, the theoretical construct of topic-specific strategies and the scientific mechanism of phases of the moon were defined. This helped to ensure that the analysis was grounded in relevant theoretical frameworks and that the findings were consistent with established scientific knowledge.

In the realm of topic-specific pedagogical strategies, knowledge can be bifurcated into two primary components: knowledge of activities and knowledge of representations. Knowledge of activities encompasses the various activities and instructional techniques employed to impart specific scientific information, while knowledge of representations pertains to the use of drawings, analogies, figures, models, simulations, and visualizations (Magnusson et al., 2006). Within this context, the term "strategy" denotes the teaching techniques implemented during the instruction of a given topic. Although the terms "teaching technique" and "teaching method" are frequently utilized interchangeably, they possess subtle differences in meaning. A teaching method, such as learning cycles, problem-based learning, or expository teaching, is a systematic, step-by-step instructional process designed to cover the instruction of a topic over the course of one or multiple class sessions (Anthony, 1963). In contrast, teaching techniques, which may include the use of analogies, demonstrations, simulations, or questioning, are specific instructional processes tailored to address particular challenges associated with a specific concept. These techniques serve to support an instructional method during the teaching process and typically require only a few minutes to execute (Anthony, 1963). The primary focus of this study was to examine the efficacy of pre-service science teachers in properly utilizing teaching techniques while engaging in the interpretation of scientific concepts.

In addition to the clarification of teaching strategies in the context of this study, it is essential to explore the scientific normative explanation of the moon's phases. The varying appearances of the moon result from the interactions within the sun-earth-moon system. A comprehensive scientific explanation of the moon's phases typically incorporates several mechanisms. Primarily, the moon orbits almost around the Earth. As the moon is spherical, only half of it is illuminated by the sun at any given time, and consequently, only half of the moon can be observed from Earth. The phases of the moon arise from the varying perspectives of the illuminated side of the moon as viewed from Earth while it orbits around our planet. For instance, when the moon is positioned between the sun and Earth, the illuminated half of the moon is not visible from Earth. In contrast, when Earth is situated between the moon and the sun, an observer on Earth can see the entire illuminated half of the moon. This specific phase is referred to as the full moon.

Trustworthiness

This qualitative study heavily relies on the researcher's interpretations; however, several measures were taken to ensure the trustworthiness of the research. It is important to note that the researcher's interpretations were not based on a single data source. Instead, pre-service science teachers' instructional plans, interviews, and instructions were triangulated to corroborate assertions. This helped to ensure that the findings were grounded in multiple sources of data, and not solely reliant on the researcher's interpretation of a single data source. Furthermore, the researcher is also a lecturer of the course from which the data was collected, having interacted with the participants for several months. This established rapport between the instructor and pre-service science teachers allowed the latter to focus on their instruction of the moon's phases without concern for academic or social perception. This rapport contributed to the acquisition of rich and reliable data from the pre-service science teachers' engagement with the topic of the moon's phases. In addition, researchers in qualitative studies must preserve the natural environment and characteristics of an issue while collecting data (Bogdan & Biklen, 1992). As the researcher in this study is also the course instructor, the participants' natural environment was not disrupted by an external party, thus preventing any potential unusual reflections from the participants. This helped to ensure that the pre-service science teachers' reflections were not influenced by external factors, which could have potentially led to unusual responses.

Limitations

The research is constrained by three limitations. One limitation inherent in this research is the restricted timeframe allotted for data collection, specifically 40 minutes per pre-service teacher. This time restriction might have limited participants from providing more topic-specific strategies with an extended duration. The short data collection period could have influenced breadth of the information gathered, potentially limiting the richness of the finding. Furthermore, it should be noted that no financial support was provided to the pre-service science teachers. The instructional setting consisted solely of one computer and a connected projection device, and all other tools and materials were acquired by the teacher candidates through their own financial means. The absence of any financial assistance or material support from institutions may have imposed constraints on their choices of teaching methods and techniques. The final limitation relates to the absence of a measurement to assess the conceptual understanding of pre-service science teachers concerning the phases of the moon. Consequently, the research lacks the capacity to explore the potential correlation between the pre-service science teachers' understanding of lunar phases and their instructional decision-making processes. This gap restricts the thorough examination of the relationship between conceptual understanding and instructional choices of pre-service science teachers.

FINDINGS

Techniques for instructing on phases of the moon

In the present study, all participating pre-service science teachers crafted instructional designs adhering to student-centered pedagogical approaches. They incorporated various activities and representations into their lesson plans. These pre-service science educators employed three distinct methods for teaching the topic of lunar phases: the learning cycle, role-playing, and argumentation. An analysis of the implemented teaching practices revealed that all pre-service science teachers employed questioning and lecturing at various stages of their instructional designs. In addition to these prevalent teaching techniques, the pre-service educators supplemented their instruction with eight alternative techniques. Table 1 enumerates the instructional techniques utilized by the pre-service science teachers in this study.

Table 2. Pre-service science teachers' techniques to teach lunar phases

Name	Activities and Representations
Amber	Modelling, Discussion
Aria	Simulation, Visual Demonstration
Zephyr	Modelling, Simulation
Lark	Modelling, Video
Nova	Discussion, Simulation
Orion	Modelling, Simulation, Worksheet
Basil	Discussion, Drawing, Game,
Frost	Modelling, Drawing, Analogy

The participants in the study showed a variety of preferences for instructional techniques. Modelling was the most preferred technique, with five out of eight participants indicating a preference for it. Simulation was also a popular choice, being chosen by four participants. Discussion was chosen by three participants, while drawing was chosen by two participants. These results suggest that participants may prefer instructional techniques that allow them to actively engage with the material, such as modelling and simulation, as well as techniques that encourage discussion. In the following section, how pre-service science teachers utilized instructional practices were explained respectively.

Modeling the phases of the moon

In current research, it has been demonstrated that pre-service science teachers predominantly favor the utilization of physical models as an instructional approach for elucidating the phases of the moon to students. Three distinct modeling techniques for teaching the lunar phases have been identified. Zephyr, Frost and Lark utilized almost the same physical models. They selected their two of their classmates to illustrate the appearance of the phases of the moon. While one pre-service teacher, who is a classmate of the instructing pre-service teachers, stands and holds a light source, another pre-service science teacher, also a classmate, manipulates a Styrofoam ball and rotates it. In this way, light illuminates different parts of the Styrofoam ball and pre-service science teachers can observe changes of the illuminated portion of the Styrofoam ball as seen Figure 1. Pre-service science teachers briefly instructed how to perform these modeling activities. At the end of the activities, pre-service science drew and discussed their observation.

Figure 1. Classmates' performance with models in the instruction by pre-service science teachers

Amber preferred approach involved creating a self-made model to illustrate lunar phases. This model was constructed using a cardboard base with eight Styrofoam balls affixed to it and a hole in the center. One edge of the cardboard was designated as the point where sunlight would enter, and half of the Styrofoam balls, specifically the side not facing this edge, were painted black. As depicted in Figure 1, Amber' classmates rotated their heads to observe the changes in lunar phases. In contrast to Amber's technique, Orion employed a group activity utilizing playdough. Initially, he distributed a sheet featuring images of four distinct lunar phases. Subsequently, he instructed his classmates to create a model of the sun-earth-moon system using playdough, with each component corresponding to a particular moon appearance. The groups subsequently presented their models and, with the aid of the simulation, engaged in a discussion to verify the accuracy of their representations. Upon comparison, it was evident that Orion's model did not effectively demonstrate the process of moon illumination. He acknowledged that his model's absence of a light source rendered it incapable of visualizing the process. Consequently, the model only depicted the positions corresponding to specific lunar phases, limiting its overall effectiveness in teaching the concept comprehensively.

Pre-service science teachers' preference for physical models can be attributed to the effectiveness of these models in addressing misconceptions commonly associated with lunar phases. They believe that teachers can effectively facilitate students' comprehension of the phenomenon by employing physical models. This approach emphasizes that the varying lunar appearances result from the moon's illuminated portion as it orbits Earth, rather than being a direct consequence of Earth's shadow on the moon. For example, Amber states:

> There was a misconception about the Earth's shadow falling on the moon. It's a pretty common misconception, even present in the classroom. To show that this isn't the case, the sun's rays hit one side of the moon. From Earth, we see it like this. I wanted to explain this concretely. They had already learned that it was illuminated. When the light hits, it brightens up. That's why I made that part of the model white. The other side is dark.

In interviews conducted with pre-service science teachers, they also expressed their belief that the models they use also effectively represent the moon's rotation and revolution movements. They think that these physical representations not only help students understand the lunar phases but also provide a comprehensive understanding of the moon's movements in relation to the Earth. By utilizing these models, teachers can visually demonstrate the complex processes behind the moon's orbit, enhancing students' grasp of fundamental astronomical concepts and fostering a deeper appreciation for the intricacies of our natural satellite's behavior.

Simulation

Four pre-service science teachers employed various lunar phase simulations, which shared similar characteristics. Each simulation's screen comprised two frames: one displaying the moon's orbit around the earth, and the other illustrating the changing appearance of the moon during its orbit. The simulations used by Nova and Orion also included a third frame, showcasing the orientation of the moon and sun in the sky. Three pre-service science teachers, Aria, Zephyr, and Orion did not allow their peers to modify the simulation conditions. Instead, they set up the simulation, and their classmates observed the changes. Conversely, Nova provided computers and simulations setups for each group of classmates, who subsequently utilized the simulation to derive conclusions regarding the moon's phases.

Aria employed the simulation to elucidate the mechanism of lunar phases, explaining the occurrence of each phase and demonstrating it through the simulation. Zephyr utilized the simulation to reveal that the moon is visible during the daytime, while Orion integrated the simulation to verify whether the pre-service science teachers' models accurately represented specific lunar phases. Additionally, Nova incorporated the simulation into an argumentation activity to display earth-based and space-based perspectives of the sun-earth-moon system.

Frost expressed her thoughts on the potential incorporation of simulations in her instruction of the lunar phases, especially if given the chance to refine her teaching methodology. S/he explained the limitations of her current method, stating, "After all, we are in a classroom setting. I only have a plastic ball in my hand, which might not be sufficient to visualize the concept for the students." Recognizing that today's students are accustomed to using computers and tablets, she suggested that simulations could be more effective for engaging them. Frost further elaborated, "Simulations involve numerous parameters, which indicate their basis in a scientific framework. This aspect could make them particularly appealing to students." By incorporating simulations into her lessons, Frost aims to enhance the learning experience, leveraging technology to foster a deeper understanding of complex astronomical concepts in a manner that resonates with contemporary students.

Video

Lark was the only pre-service science teacher who incorporated a video related to lunar phases into her instruction. She utilized a video titled "Outer Space Time to Shine: The Moon Song by StoryBots" at the beginning of her lesson. The video featured a song and visual demonstration of the sun-earth-moon system. Lark employed this video as a warm-up activity, with the aim of reminding pre-service science teachers about the moon's rotation and revolution, as well as the shapes of the earth, sun, and moon. After watching the 2-minute-long video, Lark provided a summary of the concepts presented within it.

Figure 2. Video demonstration

Game

Basil opted to engage her classmates in a game while teaching the phases of the moon. In this activity, students would throw a ball to another student and ask a question related to the sun-earth-moon system. The game continued with the ball being thrown and questions being asked among the students. Basil began her instruction with this game to activate the students' prior knowledge. The questions, predetermined by Basil, encompassed topics such as "naming a lunar phase," "describing the shape of the moon," "drawing a lunar phase," and "demonstrating their movements."

Drawings, visual demonstrations, and worksheets

Drawings and visual demonstrations were common techniques employed by most of the pre-service science teachers. They utilized smartboards or worksheets for visual representation and drawings. For example, Orion distributed a worksheet displaying the appearance of the four lunar phases. He asked the students to draw the positions of the sun, earth, and moon to illustrate these lunar phases. Frost preferred drawing the phases of the moon on the board while explaining why we observe lunar phases. She sketched eight orbital positions of the moon while the sun illuminated it. Then, she demonstrated how a person on earth would observe the moon from those positions, as shown in Figure 3.

Figure 3. Drawing lunar phases on the whiteboard

Aria incorporated photos into her presentation with the aim of showing that the moon is visible during the daytime. Consequently, the images depicted some of the moon phases observable in the daytime. The image utilized by Aria is presented in Figure 4.

Figure 4. Visual demonstration

Discussion

Nova, Amber, and Basil chose to incorporate group discussions into their instruction on the phases of the moon. Each of these discussion activities had distinct characteristics and purposes. Both Basil and Nova aimed to facilitate a deeper understanding of lunar phases among pre-service science teachers by exploring their ideas on the topic. Meanwhile, Amber's objective was to teach the reasons behind lunar phases through discussion.

Basil presented four national flags and asked students to identify differences and similarities of the moon depicted on these flags. She also asked students to consider the geographic locations of the countries. Following the discussion, Basil explained that the moon's orientation can change depending on one's location. In Amber's instruction, the classmates discussed the reasons behind the observation of different lunar phases. She incorporated the discussion segment after the model demonstration. The students observed various lunar phases through the model and then discussed the rationale behind them. On the other hand, Nova provided three graphs displaying the appearance of the sun and the moon in the sky. The positions of the moon and the sun, as well as the phases of the moon, differed in all three graphs. Nova asked students to examine which of the scenarios would be impossible to observe from the earth. Students discussed the problem within their groups and attempted to find a logical answer.

During their instruction on lunar phases, pre-service science teachers often utilize the questioning technique as a means to engage students and encourage critical thinking. By posing thought-provoking questions, teachers can effectively stimulate discussions and encourage students to actively participate in the learning process. For example, Frost employed this technique by asking her classmates whether they believed the moon was not a source of light. This question not only encouraged students to consider the nature of the moon's illumination but also provided an opportunity for Frost to address potential misconceptions, clarify the role of the sun as the primary light source, and ultimately deepen her classmates' understanding of the underlying mechanisms responsible for the moon's various phases.

Among the pre-service science teachers, Nova expressed her intention to revise and integrate the questioning technique into her lessons if given the opportunity. She believes that employing this approach would enhance her instruction on the phases of the moon. Specifically, Nova mentioned that she would pose questions to the students about the stages in which solar and lunar eclipses occur during the moon's cycle. By incorporating questioning into her teaching, Nova aims to deepen her students' understanding of the complex interplay between the sun, the moon, and the Earth that gives rise to these fascinating astronomical phenomena.

Story

Only one pre-service science teacher, Aria., shared a story with her classmates. She incorporated a brief narrative related to the evolution of our understanding of lunar phases. The story, which is included in the lesson plan, is outlined in the following excerpt.

> Ancient Greeks believed that their Goddess Selene's shiny crown illuminated the moon, and they used the phases of the moon as a measure of time. In fact, they considered the period from one full moon to the next as one month. The teacher continued, explaining that many ancient people believed the moon had its own light. However, the Greek philosopher Anaxagoras posited that the moon was a rocky body, reflected sunlight. In 1065, Chinese philosopher Shen Kuo observed and deduced that the shape of the moon was spherical. He also explained the reasons for the moon's phases. Furthermore, with the advancement of technology and the invention of the telescope, the moon was observed in greater detail.

Aria included this story in her instruction to emphasize the tentative and empirical-based nature of science. By highlighting the historical development of our understanding of lunar phases, she aimed to demonstrate how scientific knowledge evolves over time through observation, experimentation, and the refinement of ideas. This approach helps students appreciate the ever-changing and progressive nature of scientific inquiry, as well as the importance of advancing our comprehension of natural phenomena.

Analogy

Among the pre-service science teachers, it was observed that only Frost employed the analogy technique in the lesson on the phases of the moon. At the beginning of her explanation, Frost posed a question regarding how an apple is illuminated by a candle. As seen in Figure 5, she drew a comparison between the apple and the moon, illustrating that just as the candle illuminates the apple, the sun similarly illuminates the moon. By utilizing this analogy, Frost aimed to facilitate the classmates' understanding of the relationship between the sun and the moon, and how their interaction results in the observable lunar phases.

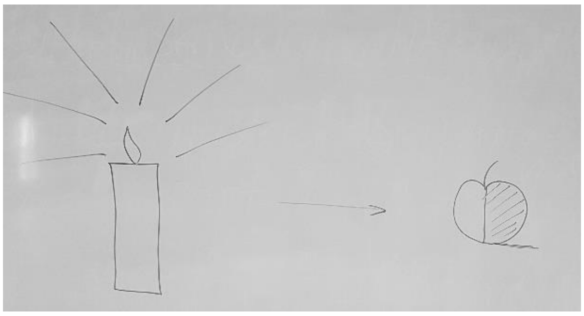

Figure 5. Moon’s illumination analogy

Challenges of Pre-service Science Teachers’ Instruction on Phases of the Moon

Shadows Falling on the Face

The infrequency of solar and lunar eclipses can be attributed to the approximately 5-degree inclination of the moon's orbit relative to Earth's orbital plane. This inherent tilt results in the moon generally being positioned above or below the ecliptic during the new and full moon phases, which are essential for eclipses to occur. In various model demonstrations conducted by pre-service teachers, it has been observed that the lunar models were not held at an appropriate angle to accurately represent the actual inclination. Consequently, instead of effectively illustrating the new and full moon phases, the demonstrations inadvertently depicted solar and lunar eclipse events, as shown in Figure 6. This highlights the importance of precise model manipulation and a thorough understanding of celestial mechanics to ensure accurate representation and comprehension of astronomical phenomena in educational settings.

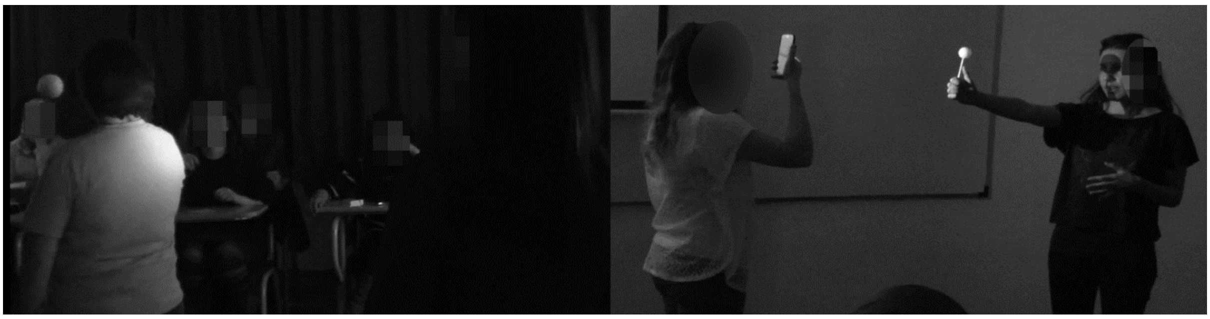

Figure 6. Shadow problems in model usage

As illustrated in Figure 6, during the full moon phase, the student's shadow falls onto the ball, while in the new moon phase, the ball's shadow is cast onto the student's face. This highlights the importance of precise model manipulation and a thorough understanding of celestial mechanics to ensure accurate representation and comprehension of astronomical phenomena in educational settings. The aforementioned discrepancy in the pre-service science teachers' model demonstrations underscores a potential gap in their awareness of the intricacies involved in accurately representing astronomical phenomena.

Lunar Phase Representations

In the research, it was observed that pre-service science teachers employed a variety of activities to instruct on the phases of the moon. Some opted for three-dimensional models and drawings as tools to facilitate understanding of the reasons behind the appearance of lunar phases. However, these pre-service science teachers encountered challenges in translating their observations from three-dimensional models to two-dimensional representations. Notably, difficulties arose when attempting to accurately depict the shapes and positions of the waxing and waning gibbous and crescent moons in their drawings. This finding underscores the complexities involved in the process of transferring knowledge between different representational formats within the context of teaching lunar phases. For example, as seen in Figure 7, Lark was unable to accurately draw the positions and shapes of the crescent phases in the lunar phases diagram, which was created together with the students after the model demonstration.

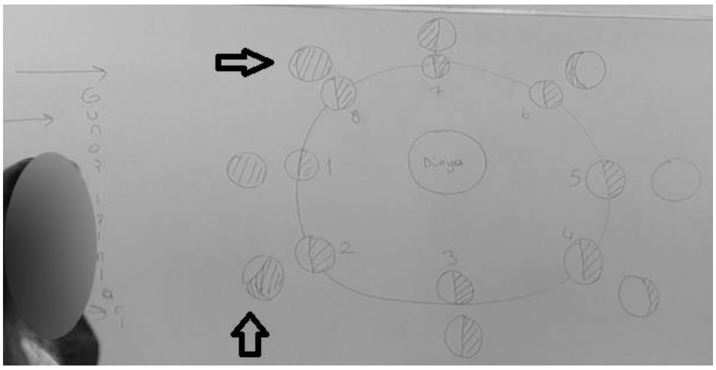

Figure 7. Lark's inaccurate crescent depiction

Space-based and earth-based awareness

It has been observed that some pre-service science teachers lack an awareness of the distinguishing characteristics between the Earth-based and space-based appearances of the moon. For instance, Aria confused the moon's appearance from space and its view from Earth. This issue is evident in both her verbal explanation and her demonstration of lunar phases using a simulation. Aria tried to explain the phases of the moon; however, their explanations and demonstrations made understanding the idea challenging. While showcasing the lunar phases via simulation, Aria stated, "Following the new moon, we see the crescent moon, where the moon's edge is facing the sun." It is important to note that the moon's edge is not actually facing the sun; rather, half of the moon is always illuminated by the sun. Her statement and demonstration during the interview underscore the confusion arising from differentiating between space-based and Earth-based perspectives of the lunar phases, which is seen in Figure 8.

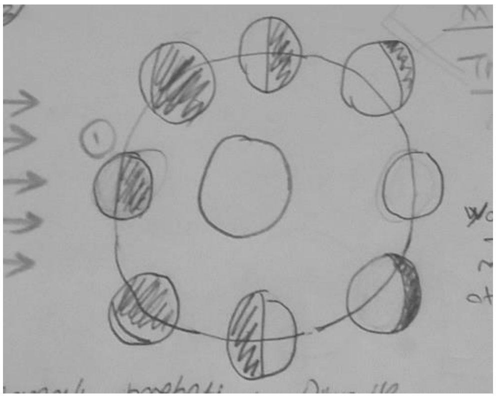

Figure 8. Space-based and earth-based awareness

Half Moon Fallacy

There are some pre-service science teachers to refer to the first and last quarters of the moon as a "half-moon," rather than using the appropriate terminology. While looking at the first and last quarter moon, it is perceived that we observe half of the moon. Therefore, pre-service science teachers describe the first and last quarter moon as a half-moon. However, we observe a quarter of the moon in these phases. In the interview, Amber stressed that memorizing the moon's name was difficult for her. More specifically, she underlined the difficulty of determining the appropriate name of the phases considering their apparent parts from the earth.

Daytime Lunar Visibility

The moon is visible during the daytime due to its position in relation to the Earth and the sun, which allows it to reflect sunlight towards the observer on Earth. The visibility of the moon during daytime is contingent upon its various phases. For instance, during the waning gibbous phase, the moon can be observed during late morning and afternoon hours. The limited observable knowledge of pre-service science teachers regarding the moon has led to difficulties in explaining the moon's daytime appearance to their classmates.

Addressing daytime lunar visibility, Zephyr encounters difficulties while explaining lunar phases using a simulation, as her beliefs about when the moon becomes visible conflict with the scenarios presented in the simulation. Zephyr believes that during daytime, the moon only becomes visible when the sun is close to setting. While explaining the lunar phases with a simulation, she states, "As the sky darkens, we start to see the moon." However, during the simulation, a scene appears where the moon is visible at daytime while the sun is at its zenith, prompting one of the pre-service teachers to point out the inconsistency with Zephyr’s statement. After a moment of consideration, Zephyr claims that the simulation presents an idealized image and that such a situation is not possible in real life.

In contrast to Zephyr's case, Aria approached the topic of daytime lunar visibility differently, focusing on students' understanding of the moon's phases and using photographs to illustrate her points. Aria asked students whether we observe the moon during daytime to elaborate on students' understanding of lunar phases. However, after the students’ responses, she demonstrated photographs showing the moon's appearance during the daytime and explained.

> First, to see the moon during the day, the moon must be at a certain height. Depending on its position, it should receive sufficient light from the sun. When these conditions are satisfied, we can observe the moon in the daytime.

Aria's explanation aligns with the real situation to some extent. The visibility of the moon during daytime does indeed depend on the moon's position in the sky and the amount of sunlight it receives. However, the key factor influencing daytime visibility is the moon's current phase. Similar to Zephyr, Aria lacks sufficient lunar observation experience, which prevented her from adequately presenting the relationship between the moon's phases and visibility to her peers. An effective teaching technique could have involved providing information about the moon's phases and discussing whether they are visible during the day, as well as the specific time intervals during which they can be observed.

DISCUSSION, CONCLUSION AND RECOMMENDATIONS

The focus of the study was to examine pre-service science teachers’ instruction on phases of the moon. Specifically, the current study aimed to identify the teaching techniques that are favored by pre-service science teachers, as well as the challenges they encounter when implementing these techniques. The result of the study revealed that pre-service science teachers instructed adopted a student-centered perspective and integrate several teaching techniques into their lessons when instructing on the phases of the moon. However, despite their efforts, pre-service science teachers encountered various challenges during the instructional process.

Modeling is one of the most frequently used and effective techniques in the teaching of the moon phases and supports students to acquire an appropriate conceptual understanding (Mills et al., 2016). Profound conceptual development occurs during the process of converting information to physical models when the students are actively involved in the modelling process (Shen & Confrey, 2007). However, previous studies emphasized that failure to achieve the desired effect with the model might be attributed to the lack of adequate control of the scientifically accuracy of the model (Mills et al., 2016) A total number of five pre-service science teachers utilized physical models. This is a rational decision, as explaining the movement of the moon is difficult using only two-dimensional diagrams (Mulholland & Ginns, 2008). It was underlined that there were many mistakes in the models made by the teachers and that the teachers were in a dilemma as to whether the models should reflect the image of the earth from the moon or the image of the moon from space. The evidence suggests that pre-service science teachers lack sufficient knowledge in constructing models related to the different phases of the moon and in evaluating the models created by their students. This finding highlights the need for further education and training for these teachers in the realm of scientific modelling.

It is necessary to be able to visualize objects from different angles and to be able to follow the movement of objects in three-dimensional space to have a comprehensive understanding of phases of the moon. The ability to imagine and visualize is important when studying the complexities of space and related phenomena (Plummer et al., 2016). The findings of the present study indicated that pre-service science teachers might encounter difficulties in their teaching practices that are related to their spatial abilities. These challenges could be related to visualizing or understanding spatial relationships, which could impact their ability to effectively teach certain concepts or subjects (Sagdic & Sahin, 2023). Pre-service science teachers with inadequate spatial skills may struggle to effectively visualize the complex three-dimensional relationships between the moon, Earth, and the sun (Black, 2005; Cole et al., 2015; Plummer, 2014). As illustrated in Cole et al. (2022) study, spatial ability of teachers is linked to their students’ success in grasping the phases of the moon. In other words, it is crucial that their teachers have an adequate proficiency in spatial reasoning in order for students to acquire a thorough understanding of lunar phases. In the current study, it is posited that the challenges experienced by pre-service teachers while teaching lunar phases might be potentially linked to their spatial abilities. For instance, pre-service teachers faced challenges when attempting to convert the three-dimensional concept of lunar phases into a two-dimensional representation, and then accurately portraying them on a model. In light of the challenges identified, integration of spatial ability assessments and targeted training within teacher education programs is recommended to better prepare educators for addressing the complexities associated with teaching subjects that demand advanced spatial skills.

Pre-service science teachers often encounter difficulties memorizing the names of lunar phases, with some preferring to use "half-moon" instead of the more accurate terms "first quarter" and "last quarter." This confusion may arise from the inconsistency between the names of the phases and their appearances, as some lunar phases are named based on a space-based perspective, while others originate from an Earth-based perspective. Previous studies (e.g., Dove, 2002; Parker & Heywood, 1998) have also identified that terminology might be a problem in understanding the phases of the moon. To cite an example, the term "full moon" is used even though only half of the moon is visible from Earth. When viewed from an Earth-based perspective, the entire visible surface of the moon appears illuminated by the sun. However, the term "first quarter" refers to a quarter of the moon being illuminated by the sun, a description consistent with a space-based perspective, rather than an Earth-based perspective. To minimize confusion while instructing lunar phases, it is essential to enhance pre-service science teachers' understanding and awareness of the various names associated with lunar phases and the perspectives they represent.

Astronomy topics can be challenging to understand and teach due to their complex nature. To achieve a thorough understanding of celestial bodies, it is imperative for students to engage in sky observations (Mant & Summers, 1993). Nevertheless, observations alone are inadequate for cultivating a comprehensive grasp of the subject matter. It is essential that students develop the ability to visualize celestial bodies in three dimensions and conceptualize their spatial movements (Wilhelm et al., 2018). Similar to various scientific fields, astronomy greatly benefits from advancements in technology and communication for its ongoing progress. These developments play a vital role in enhancing the learning and instruction of astronomy-related subjects. A diverse array of new technology-based techniques has been specifically designed to support learning of astronomy issues. Studies showed that these techniques (Beltozar-Clemente et al., 2022) contributed to understanding of individuals. In the current research, four pre-service science teachers utilized simulation as a teaching technique for the phases of the moon. Interestingly, none of the pre-service teachers employed more recent technology-supported approaches, such as mobile applications or augmented reality. In Tascan and Unal (2020) study involving teachers, a similar trend emerged, indicating that among the 26 participating teachers, only one individual reported using augmented reality applications. These findings align with broader research (e.g., Alkhattabi, 2017; Perifanou et al., 2022), which demonstrated that obstacles hindering the use of augmented reality in classrooms include the absence of essential support systems, insufficient tools for content creation, and teachers' limited knowledge of augmented reality. It is probable that the prospective teachers participating in this study might not have utilized technologies such as augmented reality in their classes due to a lack of knowledge about these new technologies or the unavailability of suitable instructional materials. Therefore, it is crucial to explore and promote the use of innovative technology-supported teaching methods in astronomy education, as they have the potential to significantly enhance students' understanding and learning experience.

Ethics Committee Approval Information

All ethical rules were strictly followed during the stages of data collection and analysis. Additionally, ethical approval was obtained from Kafkas University Social and Humanities Research and Publication Ethics Committee, with the approval document dated 06.04.22 and assigned the permission number 33, ensuring that the research adhered to ethical standards.

Funding

The author received no financial support for the research, authorship, and/or publication of this article.

Statements of publication ethics

I hereby declare that the study has not unethical issues and that research and publication ethics have been observed carefully.

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