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Improving Prospective Physics Teachers' Conceptual Understanding of Moon Phases Through an Integrated Observational and Virtual Simulation Learning

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Abstract

Although the moon's phases are directly observable phenomena, students at all levels of education consistently have misconceptions about their causes. This indicates a cognitive gap between observational experience and the scientific models that are supposed to explain it. This study aims to improve prospective physics teachers' conceptual understanding of moon phases through an integrated observational and virtual simulation learning. Employing a pre-experimental method with a one-group pretest-posttest design, the study involved a total sample of 19 students from the Department of Physics Education. The research instrument was a conceptual understanding test adapted from the Moon Phases Concept Inventory (MPCI), consisting of 11 items and accompanied by a Certainty of Response Index (CRI). The results revealed a substantial increase in students' understanding, as indicated by the mean pretest score of 2.68 (SD = 1.108; SE = 0.254) and the mean posttest score of 9.47 (SD = 1.744; SE = 0.400). The Shapiro-Wilk normality test showed that the pretest data were normally distributed (Sig. = 0.130), while the posttest data were not (Sig. = 0.001). Consequently, the Wilcoxon signed-rank test was used and confirmed a statistically significant difference between the pretest and posttest scores (Asymp. Sig. 2-tailed = 0.000). These findings indicate that combining direct observation and virtual simulation contributes meaningfully to the improvement of prospective physics students' conceptual understanding of Moon phases. These findings also illustrate the value of integrating real-world experiences and simulation technology into the physics teacher education curriculum to strengthen conceptual competencies, spatial skills, and pedagogical readiness while supporting deep learning.

Keywords: Moon phases, observation, pre-service teachers, virtual simulation.

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INTRODUCTION

One of the most discussed phenomena in schools is also one of the least understood: the phases of the moon. It is easy to observe that the moon changes shape daily. This phenomenon can be explained scientifically, but it isn't very easy to understand because it involves the movements and positions of the Earth, the moon, and the sun. How students learn and understand the phases of the moon is an interesting topic to study, because many misconceptions are found at various levels of education (Kavanagh et al., 2005). Syuhendri et al. (2022) found that there were many misunderstandings in the material of the phases of the moon, not only experienced by secondary school students but also by prospective physics teachers. Mohd Radzi et al. (2017), through their study, found that several serious misconceptions were related to elementary school students' understanding of the phases of the moon.

The main challenge is how to make students understand why the moon's shape looks different from day to day, not just see it. Students can indeed see the shape of the moon changing every night (real experience), but often they cannot connect what they see with scientific explanations, such as the position of the moon about the sun and the Earth. The primary issue that remains unresolved in understanding the phases of the moon is how to bridge the gap between concrete experience through direct observation and conceptual understanding (Nikolopoulou et al., 2024).

Although misconceptions about moon phases are common among elementary school students and college students, these issues often stem from deeper cognitive challenges, such as poor representational competence (Hartanto et al., 2025; Herder & Rau, 2022) and poor spatial reasoning (Cole et al., 2015; Plummer, 2014). Research by Barnett & Morran (2002) suggests that spatial and representational abilities interact in astronomy learning. Students need spatial abilities to manipulate mental models of celestial objects and representational abilities to transfer information between images, simulations, and observations. Students' inability to model three-dimensional relationships between celestial objects or to accurately interpret scientific visual representations contributes significantly to the persistence of these misconceptions.

Due to the difficulty in bridging the gap between what students see and their scientific concepts, many students end up having misconceptions about the phases of the moon. For example, middle-level students most often think that the phases of the moon are caused by the Earth's shadow (Cole et al., 2022). In addition, the shadows of other planets, clouds, and even the shadow of the sun are thought to cause the phases of the moon (Zou et al., 2023). Many student teachers still show misconceptions about the order of the moon's phases, the causes of phase changes, and the relationship between the relative positions of the Earth, moon, and sun (Syuhendri et al., 2022). Although students are raised in different cultural settings, research shows that misconceptions about the phases of the moon tend to appear in similar patterns across countries. These common misconceptions suggest that everyday observations without a foundation in scientific understanding can shape erroneous understandings, and that these misconceptions emerge consistently across cultures. This finding aligns with cross-cultural studies, such as those by Vosniadou & Brewer (1992), which have shown that even children from different cultures often share similar misconceptions.

Misconceptions about the phases of the moon do not just appear out of nowhere. In addition to the fact that classroom learning has not been able to bridge what students observe and their scientific understanding, other factors worsen the situation. One of the contributing factors is the mistaken assumption that astronomical phenomena (e.g., the phases of the moon) are simple materials that can be memorized without needing to be understood in depth (Hartanto & Nawir, 2017). The learning patterns that have been dominant in the classroom tend to be theoretical, minimal exploration, and do not accommodate direct experience-based approaches. In practice, teachers still often rely on lecture methods, textbooks (Bell & Trundle, 2008), and two-dimensional visual media such as pictures or posters to explain phenomena that are dynamic and require spatial understanding (Plummer, 2014).

In practice, basic astronomy education for prospective science and physics teachers still faces significant challenges. Astronomy material is not adequately allocated in both school curricula and pre-service teacher education curricula (Pujani, 2013). As a result, astronomy instruction is often limited to theoretical conceptual introductions without the support of in-depth and contextual learning experiences (Elzulfiah et al., 2015; Julianti et al., 2022). This results in prospective teachers' conceptual understanding of astronomical phenomena being suboptimal and often containing misconceptions (Elzulfiah et al., 2015; Syuhendri et al., 2022). This situation has the potential to negatively impact prospective teachers' ability to accurately transfer basic astronomical knowledge to their students.

To address the challenges in learning about moon phases, this study aims to test the effectiveness of learning that combines direct observation and interactive virtual simulation. These two approaches are combined so that student teachers get a more complete learning experience. Direct observation allows student teachers to see for themselves how the shape of the moon changes from night to night, so that they can relate learning to the reality they experience. Meanwhile, virtual simulation helps student teachers understand more difficult or abstract parts, such as the positions of the moon, earth, and sun, through animations that can be rotated, repositioned, or viewed from different angles.

This learning is based on constructivist theory, which emphasizes that student teachers will find it easier to understand concepts if they are actively involved and experience the learning process themselves, rather than just receiving explanations from the teacher (Karwasz & Wyborska, 2023). In the context of astronomy learning, this is very important because many phenomena in the sky, including the phases of the moon, cannot be observed completely in just one observation. Changes in the phases of the moon, for example, occur gradually over about a month, making it difficult to understand without the help of visual aids that can show the process in its entirety in a short time. By combining real observations and flexible simulations, it is hoped that student teachers can form a more accurate and in-depth understanding of the phases of the moon.

Empirically, several studies have shown that the use of virtual simulation media can reduce misconceptions and improve conceptual understanding in science learning, including astronomy topics (Bell & Trundle, 2008; Lin, 2016; Prima et al., 2018; Tombul et al., 2024). Rutten et al. (2012) stated that virtual simulations provide significant learning benefits, such as allowing for safe and controlled exploration of variables, but only when implemented with appropriate teacher support, clear instructional guidelines, and proper integration into the learning context. Pang et al. (2024) also stated that virtual simulations have been shown to be effective in increasing conceptual understanding, student engagement, and active learning in science classrooms. On the other hand, field observation-based learning has been shown to be effective in fostering curiosity (Gozzard & Zadnik, 2021), strengthening observational skills (Johnston, 2009), and helping students build connections between theory and real phenomena (Cole et al., 2015). Therefore, the integration of both is urgently needed so that prospective teacher students can experience holistic learning: observing in real terms and at the same time understanding invisible processes through the help of digital technology. With this kind of learning design, it is hoped that prospective teacher students will not only understand the phases of the moon more accurately but also obtain a pedagogical model that they can apply in future teaching practices.

Previous studies, such as those by Bell & Trundle (2008) and Plummer (2012), have demonstrated the effectiveness of model- and simulation-based strategies in enhancing understanding of moon phases. Bell & Trundle (2008) focused on the use of computer simulations to build conceptual understanding in early childhood student teachers. These simulations provided dynamic visualizations that allowed participants to see a three-dimensional representation of the Earth–moon–sun system. Plummer (2012), on the other hand, examined how young children develop explanatory models through informal learning experiences, emphasizing the importance of visual representations and social interactions in shaping early astronomical understandings. This study takes a different approach by implementing two integrated interventions: direct observation of celestial phenomena and computer-based virtual simulations, within the context of a more cognitively advanced student physics teacher. Thus, this study presents a more holistic and reflective learning model compared to a single-media approach (simulation only), as in Bell & Trundle (2008), or an informal approach, as in Plummer (2012). This intervention combines empirical experience, visual modeling, and conceptual reconstruction in an integrated sequence to build deeper and more lasting scientific understanding.

Another key difference lies in the learning model used, namely the predict–observe–explain (POE) framework. Students are asked to predict what will happen in a phenomenon. Then, they directly observe the phenomenon. Finally, students explain their observations and compare them with their initial predictions. In this way, POE encourages students to think critically, identify misconceptions, and develop more accurate scientific concepts (Karamustafaoğlu & Mamlok-Naaman, 2015; Kibirige et al., 2014; Marcelina & Hartanto, 2021).

This study aims to explain the improvement of prospective physics teacher students' conceptual understanding of the scientific concept of moon phases. Conceptual understanding in this context is measured based on indicators adapted from the Moon Phases Concept Inventory (MPCI) instrument from the study of Chastenay & Riopel (2020), which has been used to identify misconceptions and the development of understanding on this topic. Specifically, these indicators include students' ability to explain the causes of moon phases, the moon's visibility in the sky at various times of the day, the sequence of moon phases, the moon's orbiting the Earth as a natural satellite, and the phenomena of moon and solar eclipses. With these indicators, this study seeks to comprehensively describe how an empirical experience-based intervention and dynamic model visualization can support students' conceptual reconstruction of the scientific phenomenon of moon phases.

METHOD

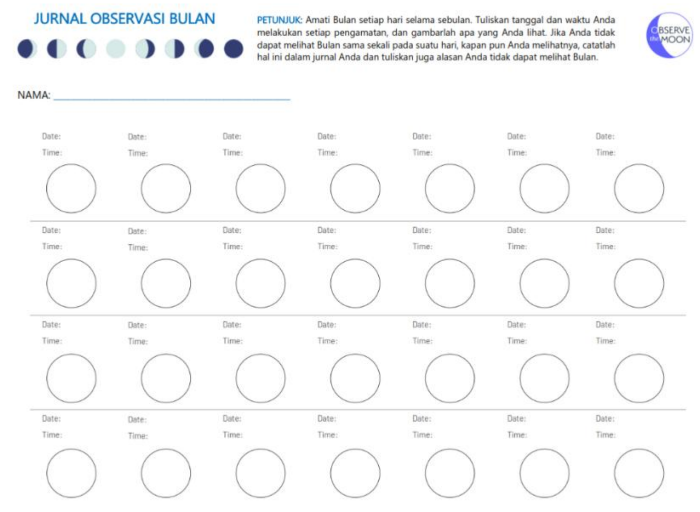
This study was a pre-experimental study with a one-group pretest-posttest design (Creswell & Creswell, 2017). In this design, one group of prospective teacher students was given a pre-test to measure their level of conceptual understanding of the moon phases before receiving the learning treatment. After that, the students participated in learning that combined direct observation and virtual simulation. At the end of the learning process, the prospective teacher students took a final test (post-test), which aimed to see the extent to which their understanding of the concept of the moon phases had increased after the learning.

The sampling technique used in this study is total sampling, where all members of the population are used as samples (Creswell & Creswell, 2017; Sugiyono, 2020). This technique is used because the population is relatively small, namely 19 prospective physics teacher students who are taking the Earth and Space Physics course.

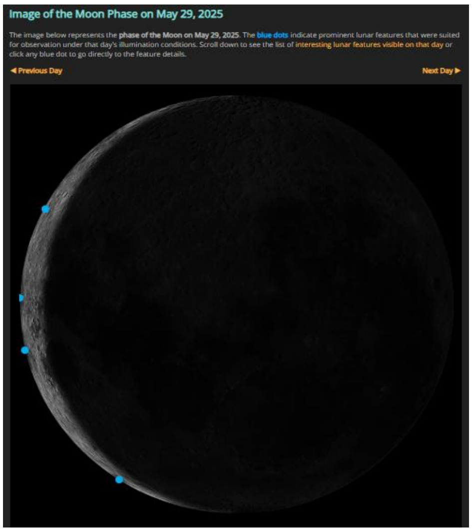
The treatment given in this study was a combination of direct observation and virtual simulation of the phases of the moon in a predict-observe-explain (POE) learning setting. POE learning has been proven effective in developing conceptual understanding and reducing misconceptions through three steps: prediction, observation, and explanation (Karamustafaoğlu & Mamlok-Naaman, 2015; Kibirige et al., 2014; Marcelina & Hartanto, 2021).

In the prediction stage, students are asked to make written predictions about the order of the moon phases and the causes of the moon phases based on their prior knowledge. This activity serves to reveal how students understand the concept of moon phases while identifying existing misconceptions. Furthermore, in the observe stage, students conduct direct observations of the moon phases for several consecutive days (throughout May 2025) and fill in the results of their observations in a daily journal (Figure 1a) and use the help of The Sky Live (Figure 1b) to assist in observations. Students record changes in the shape of the moon, the time of observation, and the relative position of the moon in the sky so that they can experience a concrete and authentic learning experience. After direct observation, students take part in a virtual simulation session provided by the Public Broadcasting Service (PBS) Learning Media Source (Figure 1c). In this simulation, students can interactively manipulate the positions of the Earth, moon, and sun to see how changes in these positions affect the appearance of the moon phases. This simulation helps students visualize dynamic and complex three-dimensional processes that are difficult to observe directly.

In the explain stage, students are asked to prepare written explanations and discuss the results of their observations, both from direct observation and virtual simulations. They are also asked to revise their initial predictions based on new understanding gained during the learning process. The lecturer facilitates class discussions to reinforce concepts, correct misconceptions, and answer questions that arise. These discussions provide an opportunity for students to integrate concrete observation experiences with conceptual understanding gained through simulations. During this stage, scaffolding is provided by the lecturer through guiding questions, prompts, and structured feedback to help students articulate scientific reasoning, connect evidence with theory, and gradually develop more accurate conceptual frameworks. The scaffolding is adjusted based on students' responses and levels of understanding, ensuring that support is reduced as learners become more confident and independent in constructing their explanations.



(a)



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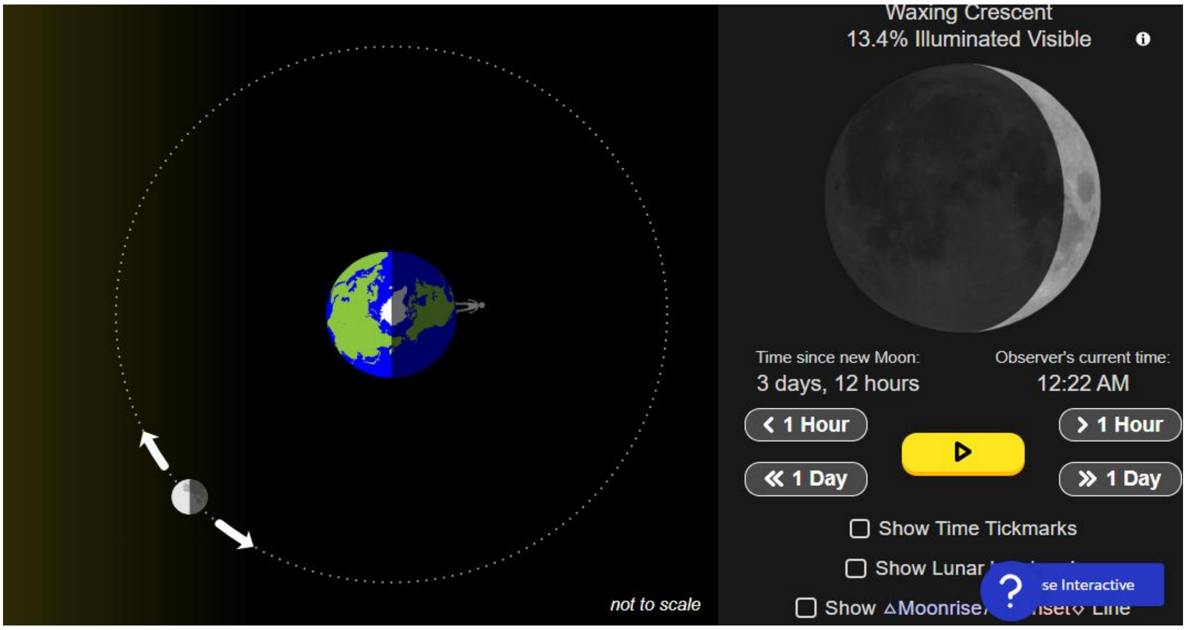

(c)

Figure 1. (a) Daily journal of moon observations; (b) Screenshot from The Sky Live; (c) Virtual simulation of moon phases from PBS Learning Media Source

The main instrument in this study was a test used as a pre-test and post-test to measure changes in students' conceptual understanding. In compiling the test, the researcher used the Moon Phase Concept Inventory (MPCI) question items from a study conducted by Chastenay & Riopel (2020), which were valid and reliable to identify conceptual understanding and reveal misconceptions related to the phenomenon of the phases of the Moon. The MPCI instrument, adapted for this study, demonstrated a fairly good level of internal consistency. Reliability analysis using Cronbach's alpha yielded a value of 0.70. This value is considered good (Kilic, 2016), indicating that the instrument's items are relatively consistent in measuring students' understanding of the concept of moon phases. Table 1 presents the grid of the understanding test of the phases of the Moon taken from the MPCI instrument from Chastenay & Riopel (2020).

Table 1. Concept understanding test grid

Question Indicator	Misconception Target	Item number
Students can explain the causes of the phases of the Moon.	The phases of the Moon are caused by the Earth's shadow, clouds, the Earth's rotation, and the Sun	1, 5, 8
Students can explain that the Moon can be seen in the sky at various times of the day.	The Moon only appears at night; The Moon rises at the same time every day, or is unpredictable	2, 4
Students can explain the order of the phases of the Moon.	The Moon's shape changes randomly	3, 10
Students can explain that the Moon orbits the Earth as a natural satellite.	The Moon does not orbit the Earth; it takes the Moon one day to orbit the Earth	6, 7
Students can explain the phenomena of moon and solar eclipses.	Eclipses can occur at any phase or are unpredictable	9, 11

Instrument adaptation was carried out to suit the curriculum context and characteristics of prospective teacher students in Central Kalimantan. In addition, adaptation was also carried out by adding open reasons and a certainty of response index (CRI) to each question item (Marcelina & Hartanto, 2021; Prodjosantoso & Hertina, 2019). The first part of the question item contains science concept questions with several answer choices. In the second part, students are asked to write down the reasons or explanations for their choices in the first part. The third part is a CRI, where students are asked to state their level of confidence in their answers. After the adaptation process, the test instrument was reviewed by several colleagues who are experts in the field of science education to ensure content validity and suitability for use in research. Figure 2 shows an example of a question item on the concept understanding test used in the study.

The data in this study were analyzed quantitatively to obtain a comprehensive understanding of changes in students' understanding of the concept of moon phases. If the answers to the first two parts are correct and he/she is confident about the correctness of the previous two choices in the third part, then the item is scored 1 point. Otherwise, the item is scored 0 points. The total score is calculated by adding the scores of each item. The total score can range from 0 to 11 points, where a higher score indicates a strong conceptual understanding and a lower score indicates a weak conceptual understanding (Taşlıdere, 2013). Furthermore, quantitative analysis was carried out on the pre-test and post-test scores using appropriate statistical tests with the help of SPSS. If the data is normally distributed, the paired sample t-test is used to determine whether there is a statistically significant difference between the pre-test and post-test results; conversely, if the data is not normally distributed, the Wilcoxon signed-rank test is used as a non-parametric alternative (Afifah et al., 2022).

SOAL 1

Abdel, Wati, Fatimah, Joko, Emilia, dan Danu sedang mengamati Bulan. Bulan tampak seperti bulan sabit tipis, seperti pada gambar di sebelah kanan. Mereka bertanya-tanya mengapa Bulan tampak seperti itu. Di bawah ini adalah beberapa pernyataan mereka. Lingkari pernyataan yang paling Anda setujui.

A. Abdel : Saya pikir bagian Bulan lainnya tersembunyi oleh bayangan Bumi atau bayangan planet lain.
B. Wati : Saya pikir ada awan atau planet yang lewat di depan Bulan.
C. Fatimah : Saya pikir jarak antara Bumi dan Bulan berubah.
D. Joko : Saya pikir rotasi Bumi menghalangi kita untuk melihat lebih banyak bagian Bulan.
E. Emilia : Saya pikir Bulan memiliki separuh terang dan separuh gelap dan ia berputar pada dirinya sendiri.
F. Danu : Saya pikir kita hanya dapat melihat sebagian kecil dari separuh bagian Bulan yang disinari Matahari.

ALASAN:

TINGKAT KEYAKINAN:

☐ YAKIN ☐ TIDAK YAKIN

SOAL 3

Maria melihat bulan sabit yang tipis di langit sekitar seminggu yang lalu. Sekarang ia penasaran, seperti apa bentuk Bulan hari ini. Teman-temannya punya pendapat yang berbeda. Lingkari nama teman Maria yang pendapatnya paling kamu setujui

A. Abdel : Aku pikir Bulan akan tampak sebagai Bulan sabit yang lebih tipis dibandingkan yang dilihat Maria
B. Wati : Aku pikir Bulan akan tampak sebagai Bulan sabit yang lebih tebal dibandingkan yang dilihat Maria.
C. Fatimah : Aku pikir Bulan akan tampak sebagai setengah lingkaran.
D. Joko : Aku pikir Bulan akan tampak bulat penuh.
E. Emilia : Menurutku tidak mungkin untuk mengetahuinya. Fase-fase Bulan berubah secara tak terduga.

ALASAN:

TINGKAT KEYAKINAN:

☐ YAKIN ☐ TIDAK YAKIN

Figure 2. Screenshot of the Moon phases understanding test item

In addition, analysis was also carried out based on the combination of answers given by students. Based on this combination of answers, the conceptual understanding of prospective teacher students is classified into several categories, namely scientifically accepted concept, scientifically accepted concept but lack of confidence, guesswork, lack of understanding, and misconceptions. The categories of conceptual understanding of prospective teacher students are presented in Table 2 (Prodjosantoso & Hertina, 2019).

Table 2. Categories of conceptual understanding of prospective teacher students

Answer (Part 1)	Reason (Part 2)	Confidence Level (Part 3)	Category
Right	Right	Sure	Scientifically accepted concept
Right	Right	Unsure	Scientifically accepted concept with lacking confident
Right	False	Unsure	Guessing
False	Right	Unsure	
False	False	Unsure	Lack of understanding
Right	False	Sure	Misconception
False	Right	Sure	
False	False	Sure	

RESULTS AND DISCUSSION

To evaluate the success of learning that combines direct observation and virtual simulation media in improving the conceptual understanding of prospective teacher students about the phases of the Moon, a series of data analyses was conducted based on the results of the pretest and posttest. This analysis includes three main stages, namely descriptive statistical analysis, normality test, and difference test for paired data groups. A summary of the results of quantitative data analysis is presented in Table 3.

Based on Table 3, descriptive statistical analysis shows a significant increase in students' conceptual understanding scores before and after participating in the learning process. The average pretest score for students was 2.68 with a standard deviation of 1.108. This value indicates that before the learning process, students' understanding of the concept of the phases of the Moon was still relatively low. After the learning intervention through a combination of direct observation and virtual simulation media, the average posttest score increased to 9.47, with a standard deviation of 1.744. In general, these data illustrate a change in the level of conceptual understanding of prospective teacher students after participating in the learning intervention.

Table 3. Results of quantitative data analysis

Test	*N*	Mean	Standard deviation	Normality Test (Sig.)	Wilcoxon test (Asymp. Sig. 2-tailed)
Pre-test	19	2.68	1.108	0.130	0.000
Post-test	19	9.47	1.744	0.001	

Based on Table 3, the results of the Shapiro-Wilk test show that the pretest data has a significance value of 0.130. Because this value is greater than 0.05, the pretest data can be said to be normally distributed. However, the posttest data shows a significance value of 0.001, which is smaller than 0.05, so the data is not normally distributed. Because one of the data groups is not normally distributed, a non-parametric test is carried out. The results of the Wilcoxon test used to test the difference between the pretest and posttest scores show an Asymp. Sig. (2-tailed) value of 0.000. The significance value is less than 0.05, which means that there is a very significant difference between the pretest and posttest results of prospective teacher students. In other words, learning with direct observation combined with virtual simulation has high effectiveness in improving prospective teacher students' conceptual understanding of the phases of the Moon.

To obtain a deeper picture of changes in students' conceptual understanding, the analysis was reviewed based on the understanding category for each test item. The understanding category was determined based on a combination of multiple-choice answers, open-ended reasons, and confidence levels (CRI). The results of this data analysis are presented in the diagram in Figure 3.

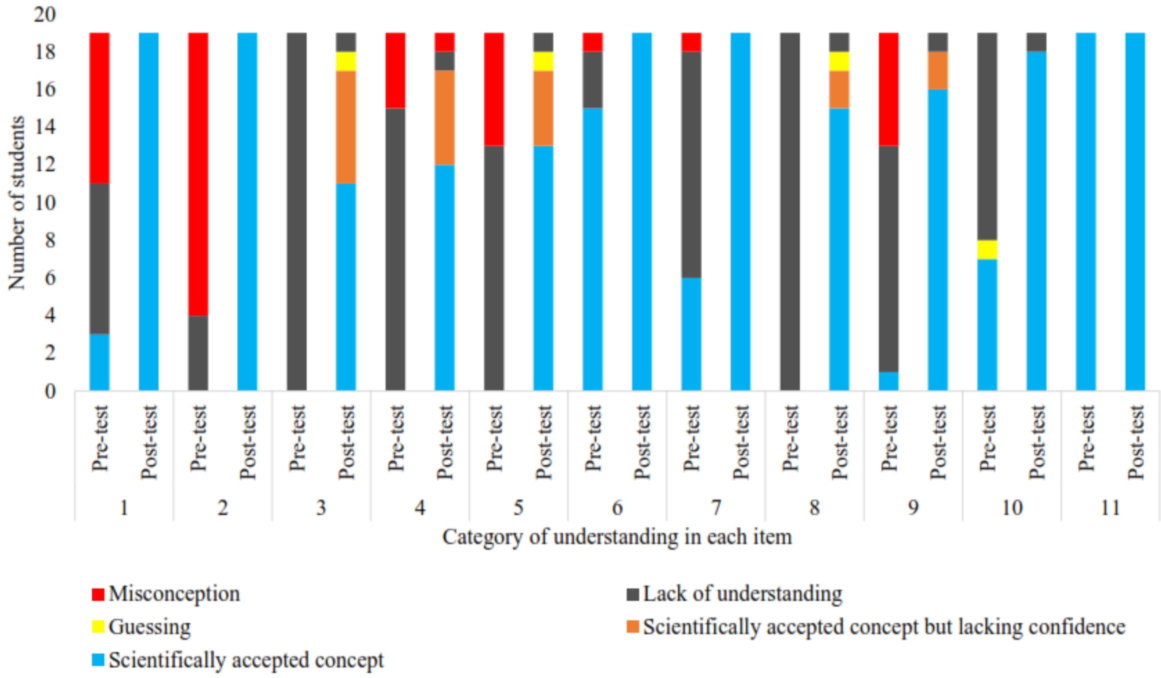

Figure 3. Results of the analysis of understanding categories in each item

Based on the answers of prospective teacher students that have been analyzed (shown in Figure 3), it can be seen that the use of learning that combines direct observation and virtual simulation media in understanding the concept of the phases of the moon has a positive and significant impact on increasing conceptual understanding. This learning has not only succeeded in increasing the number of students who are able to provide answers that are by scientific concepts but also strengthens their confidence in that understanding. This is reflected in the increase in the number of students included in the "scientifically accepted concept" category during the post-test compared to the pre-test. This means that after participating in the learning, more students not only answered correctly but also had the right conceptual reasons and high confidence in their answers. Conversely, the number of students included in the "misconception," "lack of understanding," and "guessing" categories decreased after the learning process took place.

In all the instruments used in this study, the main focus was directed at items that reveal students' understanding of the causes of the moon phases. This focus was chosen intentionally because the topic of moon phases is one of the most misunderstood concepts in basic astronomy and contains high conceptual challenges. Figure 4 presents one of the results of answers (reasons) made by prospective physics teacher students related to items related to the causes of the moon phases.

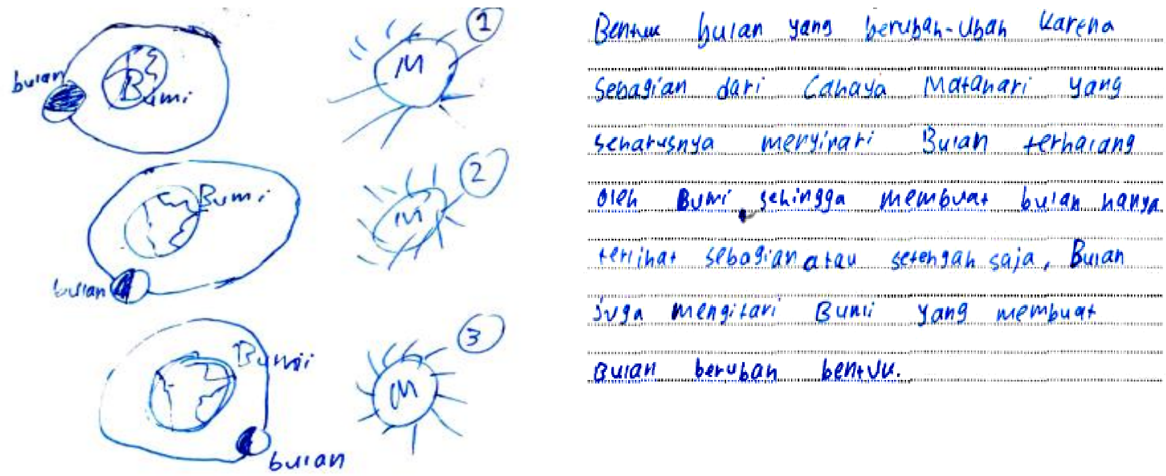

Figure 4. Example of dominant wrong answers made by students regarding the cause of the Moon's phases being the Earth's shadow

Figure 4 shows illustrations of the phases of the Moon made by student teachers based on the results of the pre-test, which reflect a misconception. The images show that students with unscientific conceptions describe the phases of the Moon as the result of the Earth's shadow covering part of the Moon's surface. In the explanations they include, it appears that students assume that the part of the Moon that appears dark is caused by the Earth's shadow, so that the different phases of the Moon are understood as the result of the position of the Earth's shadow on the Moon. This misconception reflects a common misconception that is also found in various studies on the understanding of basic astronomical concepts, such as those identified by Türkmen (2015), (Trumper (2006), Korur (2015), Cole et al. (2022), and Aydeniz & Brown (2010). These studies show that many students think that the changing appearance of the Moon from Earth is caused by the Earth's shadow falling on the Moon's surface. These results indicate that the concept of the phases of the Moon, despite being a celestial phenomenon that can be directly observed in everyday life, remains one of the most difficult astronomical concepts to understand and is prone to misconceptions that persist into adulthood (Cole et al., 2022).

Another interesting finding from the students' answers in the pre-test showed another misunderstanding that caused the phases of the Moon (as seen in Figure 5). Several students stated that the different phases of the Moon occur because the Moon receives different amounts of sunlight at different times, as if the intensity of sunlight reaching the Moon changes. This rare explanation is in line with the findings of Bayraktar (2009), who found that the Moon revolves around the Sun, causing differences in the sunlight received by the Moon. In addition, some students depicted the Moon's orbit around the Sun and Earth at the same time, which indicates a mistake in understanding the orbital system in the solar system. In their illustration (Figure 5), the Moon appears to move in a large orbit that directly encircles both the Earth and the Sun, not as a natural satellite orbiting the Earth. This conceptual error indicates that students do not yet understand the structure and dynamics of the Earth–Moon–Sun system that underlies the phenomenon of the Moon's phases (Cole et al., 2022).

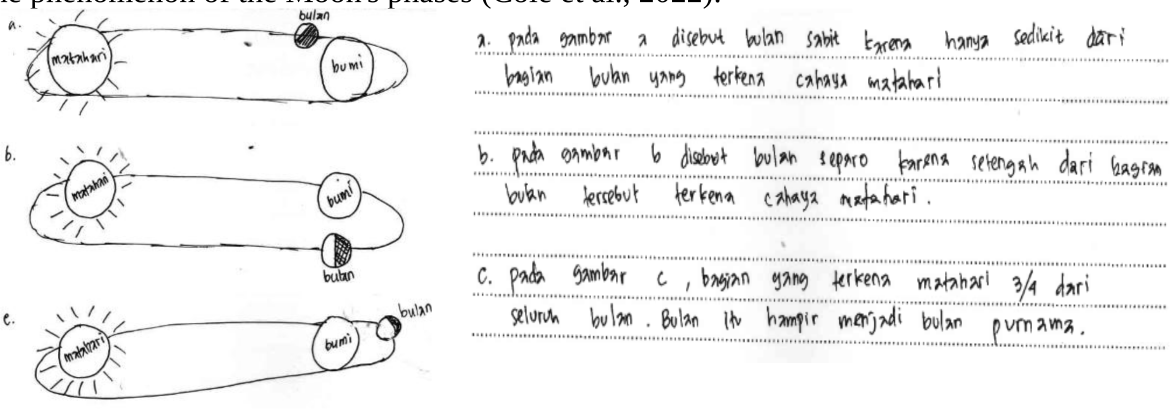

Figure 5. Example of incorrect answers made by students about the cause of the Moon's phases related to the Moon orbiting the Earth and the Sun

Students' misconceptions about the phases of the Moon, such as the assumption that the phases of the Moon are caused by the Earth's shadow or the difference in the amount of sunlight received by the Moon, can be understood through the framework of the knowledge in pieces theory (DiSessa, 2018). According to this theory, a person's knowledge is not always formed as a complete and coherent structure, but rather consists of small pieces of knowledge that are contextual and often intuitive, known as phenomenological primitives (DiSessa, 2018). These pieces of knowledge can be activated in certain situations, but are not necessarily scientifically organized (Harlow & Bianchini, 2025). Based on the answers seen in Figures 4 and 5, it can be seen that they have pieces of knowledge such as "the Moon revolves around the Earth", "the Moon looks different every night", and "light from the Sun shines on the Moon". However, these pieces are not automatically connected in the framework of understanding that the phases of the Moon are caused by the perspective from Earth of the part of the Moon that is illuminated by the Sun during its revolution. Therefore, this error does not merely indicate a lack of information, but rather indicates that the knowledge possessed has not been integrated into a cohesive conceptual structure.

After the learning was carried out, the posttest results showed a change in conceptual understanding in student teachers regarding the phenomenon of the phases of the Moon. If previously they tended to explain the phases of the Moon based on the Earth's shadow or variations in the amount of sunlight received by the Moon, then after the learning, their explanations began to show a more scientific understanding. This change is reflected in the posttest results, as shown in Figure 6, which shows students' visual representations that are more accurate and consistent with the scientific model. The students' responses in this study are in line with the results of studies conducted by (Bell & Trundle, 2008) and (Park, 2013), which stated that scientific consistency can be seen from the fact that the Moon orbits the Earth, half of the moon that is illuminated is facing the Sun, and the part of the illuminated half that we see determines the phase of the Moon.

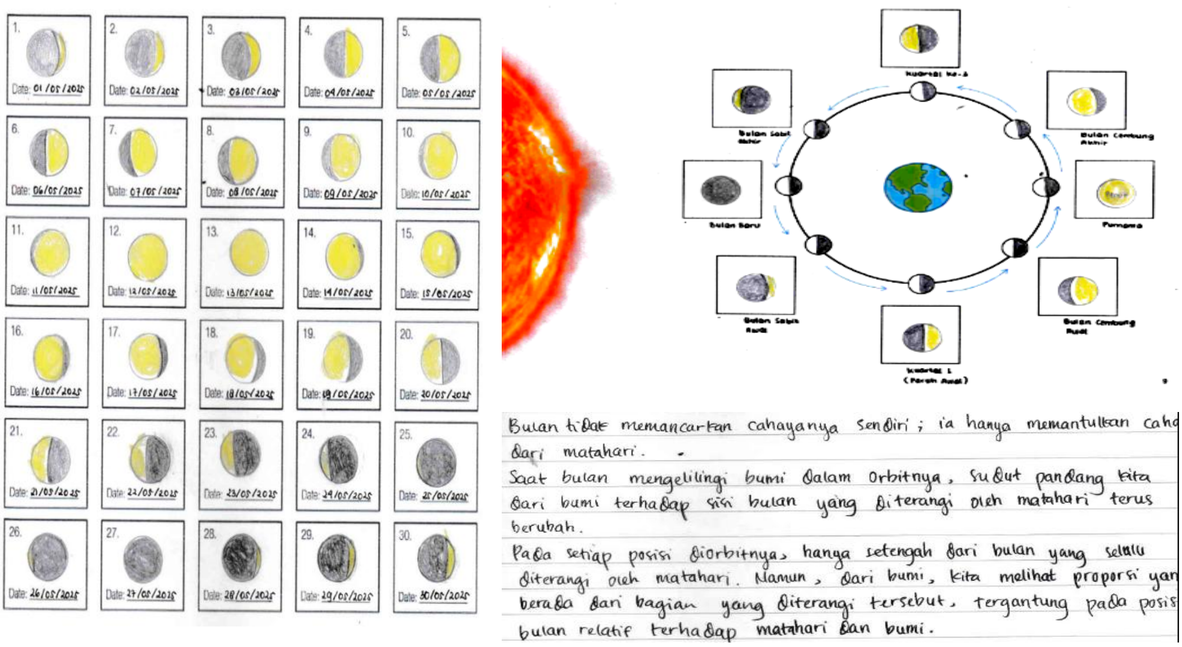

Figure 6. Example of the results of observations of the Moon in a daily journal and answers describing the phases of the Moon by students with a scientific conception

The results of this posttest indicate that the learning intervention carried out is thought to have succeeded in helping students reorganize pieces of knowledge that were previously unstructured into a more complete conceptual understanding. In the context of learning about the phases of the Moon, the integration of this knowledge is facilitated through learning that combines direct observation experiences and the use of virtual simulation media. Direct observation of changes in the appearance of the Moon from day to day allows prospective teacher students to gain concrete experiences that build initial awareness of the phenomenon. Through this observation, students begin to form questions and assumptions that come from their empirical experiences. These results are in line with a study by (Wilhelm et al., 2018), which showed that the use of a moon observation journal successfully helped students create accurate mental models needed to understand the causes of the phases of the moon. Plummer (2012) stated that learning through systematic observation and recording of astronomical phenomena improves students' understanding of the phenomena.

The results of this study indicate an increase in prospective physics teacher students' conceptual understanding of moon phases and a reduction in misconceptions, such as the assumption that moon phases are caused by the Earth's shadow or ignorance of the relative positions of the Moon, Earth, and Sun. These findings align with Bell and Trundle's (2008) research, which emphasized the effectiveness of computer simulations in fostering conceptual change, and with Plummer's (2012) research, which emphasized the importance of exploratory models and direct observation. However, this study is unique in that it combines virtual simulations with observations of moon phase phenomena within a POE framework applied to students with a strong science background in formal learning, thus providing empirical and visual experiences that reinforce deeper scientific understanding.

On the other hand, virtual simulations provide dynamic visualization (Rutten et al., 2012) of the relative positions of the Sun, Earth, and Moon, as well as changes in the Moon's appearance from the perspective of Earth and outer space. This simulation helps prospective teacher students understand geometric relationships that cannot be observed directly, such as the direction of sunlight and the Moon's revolution around Earth. In the context of basic astronomy learning, these results are relevant to the study by Bell & Trundle (2008), which shows that computer simulations used in learning can be very effective in improving scientific understanding. This simulation from PBS Learning Media is equipped with an explanatory video in the form of a 3D model that allows students to see the spatial relationship between the positions of the Sun, Earth, and Moon more clearly. Students not only witness the phenomenon from the perspective of Earth but can also observe the dynamics of the system from the perspective of outer space, so that they can understand that changes in the appearance of the Moon are not caused by the Earth's shadow but by different perspectives on the illuminated part of the Moon. Thus, the use of digital virtual simulation media has high relevance in learning the phases of the moon because it can bridge the limitations of direct observation with the need for spatial conceptual understanding. (Wilhelm et al., 2018) identified quantitative evidence supporting the idea that students' spatial abilities are related to their understanding of the phases of the moon. Cole et al. (2015) and Wilhelm et al. (2013) found that there was a correlation between spatial thinking abilities and understanding of the causes of the phases of the moon.

The conceptual changes that occurred in the students in this study were the result of a learning intervention intentionally designed to challenge and reconstruct their prior knowledge, particularly erroneous or unscientific knowledge, regarding the phenomenon of moon phases. This process can be primarily explained through the theory of conceptual change proposed by Posner et al. (1982), which states that for a new scientific concept to replace a faulty prior understanding, students must experience four key conditions: dissatisfaction with the initial concept, acceptance of the new concept, plausibility of the offered scientific explanation, and its usefulness in explaining other phenomena. In the context of this research, the POE stage systematically creates cognitive conflict between students' initial predictions and the results of observations or simulations, which is then followed by a coherent scientific explanation supported by dynamic visualizations. This process provides space for students not only to question their intuitive beliefs but also to accept and assimilate the new scientific concept more meaningfully. Thus, the learning strategy used does not simply convey information but actively facilitates the process of cognitive accommodation, as described in Posner's theory, to strengthen a more stable and applicable scientific understanding.

Students' understanding of moon phases is often influenced by intuitive reasoning, such as the belief that the moon's phases occur due to the Earth's shadow. This misconception exemplifies the rapid, automatic thinking described in Dual Processing Theory (De Neys & Pennycook, 2019; Kahneman, 2011; Marwala, 2024), where System 1 dominates: it is fast, based on visual perception, and does not require in-depth analytical thinking. Through Predict–Observe–Explain (POE)-based learning that combines direct observation of moon phenomena and virtual simulations of the positions of the Moon, Earth, and Sun, the intervention in this study was designed to activate System 2, a reflective and analytical thinking process. When students' initial predictions do not align with the results of observations or simulations, cognitive conflict arises, forcing them to question and revise their initial intuitive understanding. In this way, POE serves as a bridge from System 1 to System 2, reinforcing the process of conceptual change. Therefore, the success of this intervention is not only determined by the content of the material but also by its ability to guide students out of automatic thought patterns towards a deeper and more logical scientific understanding (Evans, 2008; Kahneman, 2011).

Although POE interventions using direct observation and virtual simulations improved understanding of moon phases, some students still retained misconceptions because conceptual change requires dissatisfaction with old ideas and recognition of the more plausible new ones (Duit et al., 2013; Posner et al., 1982). Visual and spatial misconceptions are difficult to change without active and reflective accommodation (Pundak et al., 2017). Furthermore, without in-depth information integration, students tend to absorb knowledge superficially, leading to the persistence of misconceptions (Mayer, 2002). Even when students are allowed to compare predictions with observations and scientific explanations, misconceptions can persist for several reasons. First, strong initial beliefs, especially visual and intuitive ones such as the Earth's shadow covering the Moon, are difficult to change with just one or a few learning experiences. Second, the process of reflection and revision of understanding requires time and repeated practice for new concepts to be fully internalized in the cognitive structure. Third, if the cognitive conflict that arises is not strong enough or is not followed by effective guidance to explore and question old ideas, students may tend to return to comfortable, intuitive explanations (Kavanagh et al., 2005; Syuhendri et al., 2022).

CONCLUSION

The results of this study indicate a significant increase in the conceptual understanding of prospective physics teacher students regarding the phenomenon of the phases of the Moon after participating in a learning intervention that combines direct observation and virtual simulation. This increase is reflected in the change in the average pretest score of 2.68 (SD = 1.108; SE = 0.254) to 9.47 on the posttest (SD = 1.744; SE = 0.400), which indicates an increase in understanding. The results of the Wilcoxon test showed a significant difference between the pretest and posttest scores (Asymp. Sig. 2-tailed = 0.000), which statistically strengthens the evidence that the applied learning can help improve scientific understanding. This research presents an alternative perspective on understanding moon phases by combining direct observation of natural phenomena and interactive virtual simulations within the POE framework. Unlike previous studies that focused solely on simulations, such as Bell & Trundle's (2008) study, the meta-analysis by Lin (2016), or Wilhelm et al. (2018), this research emphasizes the importance of real-life empirical experiences to strengthen the connection between theory and reality. By incorporating direct observation, this research enhances the cognitive and affective engagement of pre-service physics teachers and helps address the challenges of spatial and conceptual representation of moon phases. This multimodal approach also strengthens conceptual and pedagogical competencies, making a significant contribution to university-level physics education.

RECOMMENDATION

Although the results of this study indicate that learning that combines direct observation and virtual simulation is effective in helping prospective physics teachers build conceptual understanding of the phases of the moon, some limitations need to be considered. This approach was applied in the context of students who have an initial background in science, especially physics, so they are relatively more prepared to carry out conceptual abstraction and visual interpretation of astronomical models. Therefore, further research is needed that specifically examines how a similar approach can be adapted and applied effectively in the context of learning at the secondary education level, including the development of appropriate scaffolding strategies to avoid the recurrence of common misconceptions in students. However, these conclusions should be interpreted with caution, given the limitations of the one-group pretest–posttest design, which lacks a control group and therefore cannot fully isolate the intervention's effects from external factors. Therefore, further research with a more robust experimental design is strongly recommended to test the intervention's effectiveness in more depth and generalize the results more broadly.

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Author Contributions Statement

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Maya Mustika		✓	✓			✓	✓	✓	✓	✓	✓	✓		
Gunarjo Suryanto Budi	✓		✓	✓			✓			✓	✓		✓	✓

Conflict of Interest Statement
The authors state no conflict of interest.

Data Availability
The data that support the findings of this study are available from the corresponding author, TJH, upon reasonable request.

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