Astronomical misconceptions among South African science teachers: A case study

Khutso Charles Mogale[1], Abraham Motlhabane[1,*]

[1] Department of Science and Technology Education, University of South Africa, Preller Street, Pretoria, South Africa; motlhat@unisa.ac.za

This study explores the astronomical misconceptions of 10 South African science teachers, focusing on core concepts like earth's rotation, tilt, eclipses, seasonal shifts, day-night cycles, and planetary revolution. In-depth case studies reveal significant gaps in teachers' subject matter knowledge and pedagogical content knowledge, affecting their instructional delivery. The findings show teachers struggle with abstract concepts, often using informal language and lacking scientific precision. Many demonstrated incomplete or inaccurate understanding, highlighting the need for targeted professional development to boost conceptual mastery and instructional confidence. Limited teacher knowledge can hinder learners' opportunities to develop accurate scientific understandings, emphasizing the importance of ongoing support. This research contributes to the growing evidence on the critical role of teacher knowledge in science education, particularly in complex topics like astronomy. The study's findings have implications for teacher education, professional development, and science curriculum design, underscoring the need for sustained investment in teacher support. The research highlights the importance of addressing teacher knowledge gaps to improve science education in South Africa.

Key words:
Seasonal changes, Earth-sun-moon relationships, misconceptions in astronomy, astronomy education, pedagogical content knowledge.

Received 10/2025
Revised 5/2026
Accepted 6/2026

1 Introduction

The teaching and learning of astronomy have been a topic of interest in science education research for several decades. Studies have shown that students often hold misconceptions about astronomical concepts, such as the shape of the Earth, the movement of planets, and the causes of day and night (Dantic et al., 2024). Research has also highlighted the importance of teacher knowledge in astronomy education. Teachers' subject matter knowledge (SMK) and pedagogical content knowledge (PCK) are critical factors in determining the quality of instruction and student learning outcomes (Shulman, 1986). However, studies (Jansri & Ketpichainarong, 2020; Susman & Pavlin, 2020) have shown that many teachers lack the SMK and PCK needed to teach astronomy effectively, particularly in areas such as conceptual understanding and instructional design. The literature increasingly conceptualizes pedagogical content knowledge (PCK) and topic-specific PCK (TSPCK) as dynamic, learner-centered frameworks that shape student outcomes in 21st-century, digitally supported STEM education. Belayneh (2025) argues that PCK/TSPCK must integrate digital fluency and equity, a position supported by studies linking robust teacher knowledge to improved conceptual understanding, problem-solving, and cognitive engagement.

Complementary research by Dragnić-Cindrić and Anderson (2025) shows that project-based learning strengthens several dimensions of PCK—teaching orientations, curriculum knowledge, instructional strategies, and understanding student thinking—though assessment literacy remains underdeveloped. Astronomy education research provides particularly compelling evidence of the consequences of insufficient teacher knowledge: numerous studies reveal that both pre-service and in-service teachers hold persistent and widespread misconceptions about fundamental astronomy concepts (Kanli, 2014). Frede (2006) similarly found that most pre-service French elementary teachers possess non-scientific conceptions about the day/night cycle, seasonal changes, and even the spherical Earth model, despite these topics being part of the national curriculum since 1985. These misunderstandings often transfer directly to students, as demonstrated by Sule and Jawkar (2019), who reported that teacher-held misconceptions—especially regarding the Sun, Moon, and calendars—stem partly from difficulties in making logical inferences from existing knowledge. Intervention studies show partial improvement: Jansri and Ketpichainarong (2020) observed significant gains in teachers' celestial motion understanding after professional development, though misconceptions about seasons persisted, while Susman and Pavlin (2020) found that didactic astronomy games enhanced teacher knowledge and were viewed as educational and classroom-appropriate, despite teachers' continued lack of confidence with complex astronomical content.

Teachers play a critical role in shaping students' understanding of astronomy, and their own knowledge and instructional practices can have a significant impact on student learning outcomes.

The paper focused on the teacher's understanding of Earth's rotation, tilt, eclipses, seasonal shifts, day-night cycles, and planetary revolution, as well as their teaching approaches for these topics. By

https://doi.org/10.14712/18047106.5107
Nakladatelství Karolinum

examining the challenges and opportunities that teachers face in teaching astronomy, this research seeks to inform the development of targeted support and professional development programs that can help improve the quality of science education.

2 Theoretical background

Astronomy in South African schools is primarily integrated into the broader science curriculum rather than taught as a standalone subject. At the high school level, learners encounter astronomy through the Physical Sciences syllabus, where they study topics such as the solar system, stars, galaxies, and the origins of the universe. In the lower grades, within Natural Sciences, students are introduced to more foundational concepts like planetary motion, eclipses, and Earth's place in space. These lessons are often connected to mathematics, where geometry and trigonometry are applied to celestial measurements, and to history, where learners explore ancient African sky lore and cultural interpretations of the night sky. Importantly, it is the science teachers who deliver astronomy content to Physical Science students in Grades 10–12 and Natural Science students in Grades 7–9, ensuring that astronomy is taught within the framework of the existing science curriculum. This integration ensures that astronomy is not only presented as a scientific discipline but also as a subject that bridges culture, mathematics, and technology, making it both accessible and inspiring for learners across different stages of schooling.

Astronomy is a fundamental part of science education (Carli et al., 2025), providing insights into the universe and its many mysteries. However, teaching and learning astronomy can be challenging due to the abstract nature of many concepts, such as revolution, axial tilt, and eclipses. Research (Dantic et al., 2024) has shown that students often hold misconceptions about these concepts, which can be difficult to change and may persist into adulthood. Guerra-Reyes et al. (2024) have highlighted the significance of addressing misconceptions and enhancing conceptual understanding in astronomy education. For example, Şensoy and Asana (2025) highlight targeted efforts to tackle astronomy misconceptions through conceptual change texts, which have shown promise in enhancing pre-service science teachers' engagement with the subject. This suggests that tailored educational materials can be effective in promoting conceptual clarity among science teachers. In a similar vein, Nasution et al. (2025) investigated the use of Stellarium, a digital planetarium application, to enhance students' understanding of astronomy concepts in science education. Their findings indicate that technology can be a valuable tool in addressing the challenges of teaching astronomy, particularly in institutions with limited resources. Recent studies (Dantic et al., 2024; Guerra-Reyes et al., 2024; Nasution et al., 2025) underscore the need for innovative approaches to astronomy education that prioritize conceptual clarity and practical application.

Many studies (Guerra-Reyes et al., 2024; Rodrigues et al., 2025; Salimpour et al., 2024; Slater et al., 2018; Yu et al., 2010) have been done on misconceptions in astronomy, highlighting the complexities and challenges in understanding celestial concepts. Slater et al. (2018) investigated astronomy alternative conceptions in pre-adolescent students in Western Australia, revealing the prevalence of misconceptions even at a young age. Their findings underscore the need for early intervention and targeted educational strategies to address these misunderstandings. More recently, Salimpour et al. (2024) examined the mismatch between the intended astronomy curriculum content, astronomical literacy, and the astronomical universe, highlighting the disconnect between what is taught and what is relevant to understanding the universe. This disconnect can lead to a lack of depth in students' understanding of astronomy.

Further, Yu et al. (2010) explored student ideas about Kepler's laws and planetary orbital motions, shedding light on the specific areas of astronomy where students struggle. Their research demonstrates that students often hold onto misconceptions despite formal instruction, emphasizing the need for innovative teaching approaches that challenge these preconceptions. Danaia and McKinnon (2007) also identified common alternative astronomical conceptions in junior secondary science classes, suggesting that these misconceptions can be persistent and widespread. The persistence of these misconceptions highlights the need for teachers to have a deep understanding of astronomical concepts themselves, as well as effective strategies for teaching these concepts to their students.

The way astronomy is integrated into the curriculum can also impact students' understanding of astronomical concepts. This is because teachers may not always be aware of the misconceptions held by their students (Cox et al., 2016). For instance, Cox et al. (2016) found that teachers in Belgium had varying levels of awareness of students' misconceptions in astronomy, with some teachers overestimating or underestimating the prevalence of certain misconceptions. This lack of awareness can hinder teachers' ability to address these misconceptions effectively, underscoring the need for professional development opportunities that focus on both content knowledge and pedagogical content knowledge.

Rodrigues et al. (2025) analyzed the Chilean science curriculum and found that while there are opportunities to learn astronomy, these opportunities are not always fully exploited. This highlights the importance of curriculum design and teacher support in ensuring that students receive comprehensive astronomy education.

In South Africa, primary teachers had incorrect conceptions of the Earth-Moon-Sun system and poor conceptual knowledge in basic astronomy (Govender, 2011). Similarly, K-12 STEM teachers in the US had misconceptions about the primary source of energy for stars and the eccentricity of the Earth's orbit and showed uncertainty and hesitation in their explanations (Burrows et al., 2021). Even kindergarten teachers have been found to have a lack of knowledge and alternative ideas about scientific concepts related to time, space, gravity, and light (Ampartzaki et al., 2024). A teacher's difficulty in teaching the phases of the Moon also highlights the need for improved teacher knowledge in specific astronomy concepts (Nielsen, 2014). Overall, these findings suggest that teachers often have difficulty articulating clear and accurate explanations of complex scientific concepts. The teachers' reliance on informal language and lack of scientific precision in their explanations is particularly concerning, as it can perpetuate misconceptions and hinder learners' understanding of these concepts (Ball & McDiarmid, 1990).

Literature collectively emphasizes the importance of addressing misconceptions and promoting conceptual clarity in astronomy education. By understanding the specific areas where students and teachers struggle, teachers can develop targeted interventions to improve astronomy and foster a deeper appreciation for the subject.

The impact of teacher knowledge on student learning outcomes in astronomy is significant. When teachers have a deep understanding of astronomical concepts and effective instructional strategies, they are better able to design engaging and challenging lessons that promote student understanding and motivation (Desimone, 2009). Conversely, teachers' own misconceptions and lack of knowledge can perpetuate student misconceptions and hinder learning. Therefore, it is essential to provide teachers with ongoing support and professional development opportunities (Carli et al., 2025) to enhance their knowledge and instructional practices. Desimone (2009) emphasized the need for targeted professional development programs that focus on astronomy-specific content and pedagogy. These programs should provide teachers with opportunities to develop their SMK and PCK, as well as to design and implement effective instructional strategies. By investing in teacher knowledge and instructional capacity, teachers and policymakers can work together to improve the quality of astronomy education and promote a deeper understanding of the universe among students. While the literature offers valuable insights into misconceptions research in science education, there is limited research specifically addressing astronomical misconceptions in the South African context (Guerra-Reyes et al., 2024). In this study, misconceptions are defined as scientifically inaccurate beliefs that teachers hold in place of accepted scientific explanations, while gaps refer to instances where understanding is incomplete or missing, without the presence of an alternative conception (Chi, 2013; Robinson et al., 2011; Vosniadou, 2020). Literature on astronomical misconceptions among South African science teachers builds on a robust body of evidence demonstrating persistent conceptual challenges in astronomy education. Therefore, the study explored the following research question, what misconceptions or gaps exist in teachers' conceptual understanding of Earth's rotation, tilt, eclipses, seasonal shifts, day-night cycles, and planetary revolution, and how do these affect their instructional strategies?

3 Research methodology

This study employed a qualitative research approach (Maree & Pietersen, 2016), utilizing a case study design to explore the conceptual understanding and pedagogical content knowledge (PCK) of 10 science teachers in South Africa. The ten cases had a diverse group of Grade 7 Natural Sciences teachers with a range of qualifications and experience, from mid-career teachers like Sir Lekos (25 years) and Mam Maprezz (30 years) to experienced teachers like Mam Nandi (34 years), Sir Maps (40 years), and Sir Choss (30 years). Meanwhile, early-career teachers with less experience (between 1 and 5 years) included Sir Masemos, Sir Thobs, Mam Seaps, Sir Nkomos, and Sir Bops. Each teacher has a three-year teaching credential with a focus on either physical or natural sciences. Because astronomy content is integrated into the Natural Science curriculum, teachers do not need a specialized qualification in astronomy; a three-year science education qualification provides the necessary foundation. The grade 7 learners were between 12 and 13 years old. The names used for the teachers in this study are pseudonyms and do not represent their real identities.

Purposeful sampling of ten teachers was employed to ensure the selection of information-rich participants who possess direct experience with the phenomenon under investigation, which aligns with qualitative case study traditions that prioritize depth of insight over sample size (Creswell & Poth, 2016; Patton, 2015). We used qualitative analysis because it really helped us make sense of complex, layered data, especially interviews and classroom observations. As Merriam (1988) explains, this type of analysis allows patterns, themes, and categories to naturally emerge from the data through an inductive process, which makes it especially useful for understanding how people make sense of scientific ideas in real classroom settings. In addition, case study research gains strength when it draws on multiple data sources. This process, known as triangulation, helps improve the credibility and trustworthiness of the findings, and it's something Yin (2012) strongly advocates in his methodological work. Together, the case study design and qualitative analysis give us a solid and context-rich way to explore how science teachers understand and sometimes misunderstand—astronomical concepts, as well as how those understandings influence the way they teach.

Data collection involved in-depth interviews, which were audio-recorded and transcribed verbatim. The interview protocol focused on core astronomical concepts, including revolution, axial tilt, eclipses, and seasonal changes. Thematic analysis was used to identify patterns and themes in the data, with a focus on understanding the teachers' conceptual understanding and instructional strategies. The study's qualitative design allowed for a rich exploration of the teachers' knowledge and practices, providing insights into the complexities of teaching and learning in astronomy education.

The analysis employed a qualitative case study approach, focusing on ten individual science teachers' instructional practices and conceptual understanding of astronomical topics. Data were collected through classroom observations, teacher interviews, and content-specific probes designed to elicit explanations of key concepts such as revolution, rotation, axial tilt, eclipses, and seasonal changes. Each case was analyzed thematically to identify patterns of understanding, misconceptions, pedagogical strategies, and confidence levels. Cross-case synthesis was then used to compare individual profiles, revealing recurring challenges and strengths across the cohort. This method allowed for an understanding of both content mastery and pedagogical content knowledge (PCK) in the context of teaching abstract space science concepts.

3.1 Semi-structured interviews

This study used semi-structured interviews to explore science teachers' understanding of astronomical concepts and the challenges they face in teaching the subject. The interviews allowed for in-depth probing while maintaining a consistent structure across participants (Brinkmann & Kvale, 2018). The interviews were conducted by the authors of this paper, who specialize in science education. Given that astronomy is taught as part of the broader Physical Sciences and Natural Sciences curriculum rather than as a standalone subject, the authors' expertise aligns with the curricular context in which astronomy content is delivered. Interviews lasted 45–60 minutes. They were audio-recorded with consent and provided an opportunity for teachers to reflect on their teaching methods and professional development. The interviews were essential in collecting information that influenced participants' pedagogical content knowledge (PCK) and their sense of the social world. These qualitative interviews were the most valuable source of in-depth information, focusing on the pedagogical content challenges faced by participants. The interview included the following questions:

- How do you explain the concept of *revolution* to your learners?
- How do you help learners understand the tilting of the Earth?
- What is an eclipse, and how is it related to the positions of the Sun and the Moon?
- What causes lunar and solar eclipses? Please explain how each one occurs.
- What causes day and night in relation to the Sun, the Moon, and the Earth?
- What causes seasonal changes? Please elaborate.

3.2 Classroom observations

In addition to the interviews, non-participant observations were conducted by the authors of this paper to gather further data. An observation schedule was created, focusing on PCK components, and the authors utilized both descriptive field notes and interpretive memos. Each teacher was observed in two science lessons, lasting one hour (60 minutes), with a focus on content delivery and instructional interaction. Non-participant observations reduced interference with the study, increasing its authenticity (Marshall & Rossman, 2016). The observations allowed for the collection of data through mutual responses and questions posed to participants, providing insight into their feelings, views, acceptance, and reactions (Maree & Pietersen, 2016). The observation schedule included descriptive notes, reflective notes, knowledge focus (constructivism, teacher knowledge, instructional strategies, interaction and discourse, professional development), and pedagogical content challenges.

3.3 Data analysis

Thematic analysis was used to analyze the data, following Braun and Clarke's (2021) six-phase approach (see Fig. 1).

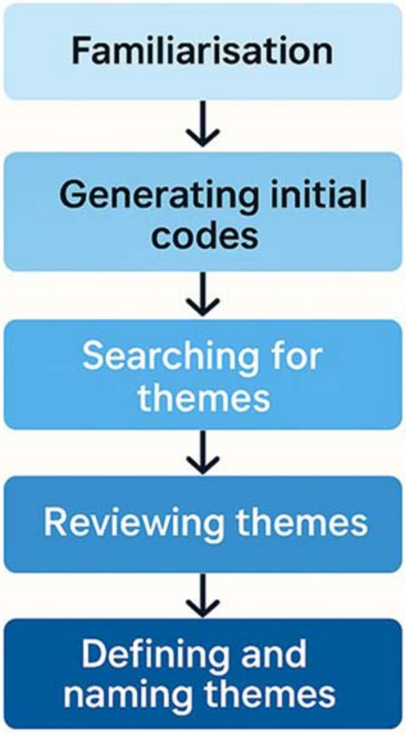

Fig. 1: Thematic analysis (Braun & Clarke, 2021)

This method was chosen for its flexibility and its suitability for exploring teachers' experiences and conceptual understandings in depth. The analysis began with a period of intensive familiarization, during which the researchers read and re-read each transcript to gain a sense of the overall patterns emerging from the teachers' responses. At this stage, early observations began to surface—particularly regarding the level of confidence and clarity with which teachers described astronomy concepts.

During the coding phase, the researchers worked systematically through the transcripts, generating initial codes both inductively and with reference to the research questions. For instance, when one teacher remarked, "To be honest, even we as teachers sometimes need clearer explanations ourselves. It's hard... to confidently teach these concepts when our own understanding isn't deep enough," this statement was coded as an example of limited content knowledge and reduced confidence in teaching astronomy. Similarly, when another teacher explained an eclipse as "the falling of the shadow of the Earth either on the sun or the moon," the coding captured the presence of misconceptions about celestial mechanics. These early codes highlighted recurring uncertainties and conceptual gaps in teachers' explanations.

As coding continued, patterns began to emerge. Teachers frequently conflated basic astronomical concepts such as rotation and revolution. One teacher, attempting to explain axial tilt, described, "When you tilt neh!... there is an imaginary line... So when we tilt, uummhh when you spin neh! It is no longer movement we call revolution." Statements like this were coded as instances of conceptual confusion and inconsistent use of scientific terminology. Other teachers expressed uncertainty about eclipses, with comments such as, "I have not revised that, but I think it is when the moon shows the dark side..." or "...the eclipse I do not remember very well... I guess those notions I forgot." These responses were coded as indicators of limited recall and the need for revision of fundamental astronomy concepts.

The third phase of the analysis involved grouping related codes into broader, preliminary themes. For example, codes relating to conceptual confusion, incorrect explanations of astronomical events, and the misuse of terminology began to cluster under the emerging theme of "persistent misconceptions". Likewise, statements expressing uncertainty, lack of revision, or insufficient confidence were grouped into a developing theme concerning teachers' limited conceptual mastery and confidence.

These themes were refined through an iterative review process, where the researchers revisited both the coded data and the full dataset to ensure coherence and internal consistency. During this stage, themes were consolidated, clarified, and strengthened. For example, individual categories relating to teachers' uncertainty, forgotten content, and low confidence were merged into a single, more comprehensive theme reflecting broader content-knowledge limitations. Similarly, misconceptions related to eclipses, seasons, and planetary motion were unified under a theme addressing conceptual inaccuracies in teachers' understanding of astronomy.

The fifth phase of analysis involved defining and naming the final themes, ensuring that each theme captured the essence of the coded data while remaining analytically distinct. Key themes included teachers' persistent misconceptions of core astronomy concepts, limited confidence and content mastery, and inconsistent use of scientific terminology. These themes reflected the most prominent challenges teachers experienced when attempting to teach astronomy.

Finally, the themes were woven into a coherent analytic narrative during the reporting phase. The teachers' own words provided rich, illustrative examples of the conceptual difficulties they faced, from describing eclipses inaccurately to confusing fundamental celestial motions. Through this process, the analysis revealed not only the gaps in teachers' astronomy knowledge but also the pressures and uncertainties that shaped their instructional practices. The findings ultimately informed recommendations for targeted professional development aimed at strengthening teachers' conceptual understanding and improving their confidence in delivering astronomy content.

4 Findings

This study presents a case analysis of ten science teachers—Mam Nandi, Sir Lekos, Mam Maprezz, Sir Masemos, Sir Thobs, Sir Maps, Sir Choss, Mam Seaps, Sir Nkomos, and Sir Bops—focused on their instructional approaches and conceptual understanding of astronomical topics. The analysis of the cases studies identified common strengths, challenges, and areas for professional development in teaching abstract astronomy concepts. The findings are presented as a thematic analysis organized into three principal areas: teachers' conceptual understanding of astronomical concepts, their pedagogical approaches, and individual teacher profiles.

4.1 Teacher's conceptual understanding of astronomy concepts

Table 1 presents a thematic summary of teachers' conceptual understanding across five core astronomical topics: revolution, rotation, axial tilt, eclipses, and seasonal changes. Table 1 highlights common strengths observed among the ten participating teachers, as well as recurring conceptual challenges that emerged during classroom observations and interviews. While many teachers demonstrated a foundational grasp of certain concepts—such as linking rotation to day and night or recognizing the role of revolution in seasonal changes, significant gaps in depth, clarity, and scientific accuracy were evident. The findings highlight that teaching about the relationship between the Sun, Moon, and Earth presents difficulties for teachers. As one of the teachers (Mam Seaps) reflected: "To be honest, even we as teachers sometimes need clearer explanations ourselves. It's hard or difficult to confidently teach these concepts when our own understanding isn't deep enough." This admission underscores the central issue identified in the study—teachers' own conceptual uncertainties can undermine their confidence and clarity in the classroom.

Table 1: Conceptual understanding of astronomy

Concept Area	Common Strengths	Common Challenges
Revolution	Most teachers could define revolution in basic terms.	Explanations often lacked clarity, depth, or were confused with rotation.
Rotation	Several teachers correctly linked rotation to day/night.	Many confused rotation with tilt or gave hesitant, vague explanations.
Axial Tilt	A few teachers attempted to use models or gestures to explain tilt.	Frequently misunderstood, omitted, or conflated with other concepts.
Eclipses	Some awareness of solar/lunar roles.	Widespread misconceptions, vague or incorrect explanations, and lack of revision.
Seasonal Changes	General link to revolution was common.	Axial tilt often omitted; explanations were oversimplified or hesitant.

Teachers' explanations of eclipses often revealed significant conceptual gaps and imprecise use of scientific language. For example, when Sir Lekos was asked what causes lunar and solar eclipses, the teacher responded: "It is caused by the falling of the shadow of the earth either on the sun or the moon." This explanation reflects a partial understanding of shadow phenomena but conflates the distinct mechanisms of solar and lunar eclipses. Scientifically, a solar eclipse occurs when the Moon passes between the Earth and the Sun, casting a shadow on Earth, while a lunar eclipse occurs when the Earth passes between the Sun and the Moon, casting its shadow on the Moon.

The teacher's phrasing, "falling of the shadow of the earth either on the sun or the moon", not only misrepresents the geometry of these events but also risks reinforcing misconceptions among learners. Such oversimplification obscures the critical role of alignment between celestial bodies and fails to distinguish between the two types of eclipses.

This overview provides a snapshot of the collective conceptual landscape, serving as a basis for identifying targeted areas for professional development.

Table 1 summarizes the common strengths and challenges observed across the ten teachers in their understanding and instruction of key astronomical concepts. Most teachers were able to provide basic definitions of revolution and correctly associated rotation with the occurrence of day and night. However, their explanations often lacked depth and precision, with frequent confusion between rotation and revolution. Teachers' explanations of astronomical concepts often revealed gaps in depth and scientific precision. For example, when Mam Nandi was asked how they explained the concept of *revolution* to learners, Mam Nandi responded: "Eeeeeeh yah, revolution is the travelling of the planet or the bodies because there are also the asteroids of bodies around the sun on their orbit which is as simple as a path." While this response captures the idea of orbital motion, the explanation is vague, conflates different celestial bodies, and lacks the clarity needed to distinguish Earth's revolution around the Sun from other orbital phenomena. Axial tilt was occasionally demonstrated using models or gestures, yet its scientific significance—particularly in explaining seasonal changes—was frequently misunderstood or omitted. While there was partial awareness of the roles of the sun and moon in eclipses, widespread misconceptions and vague explanations were evident. Seasonal changes were generally linked to the earth's revolution, but the critical role of axial tilt was often neglected, resulting in oversimplified accounts. These patterns highlight the need for strengthened content knowledge and pedagogical clarity in teaching abstract astronomical phenomena.

4.2 Pedagogical approaches of teachers

The data revealed that several teachers incorporated physical models and gestures when teaching astronomical concepts, which may form part of a broader constructivist strategy if combined with learner-centered activities. Teachers like Sir Thobs, Sir Masemos, and Sir Choss demonstrated efforts to make abstract ideas more tangible through visual aids; however, these attempts were frequently undermined by conceptual confusion and vague terminology, which limited their instructional effectiveness. Additionally, the use of informal or imprecise language was a recurring issue across multiple cases, often obscuring scientific meaning and increasing the risk of learner misconceptions. Compounding these challenges, teachers such as Mam Seaps, Sir Maps, and Sir Bops openly acknowledged not revising key content areas, which contributed to hesitant delivery and incomplete explanations. These findings highlight the interplay between pedagogical strategies, language clarity, and content preparedness in shaping the quality of science instruction.

4.3 Individual teacher profiles

Table 2 presents a summary of individual teacher profiles, highlighting both their instructional strengths and areas requiring development in the context of teaching astronomical concepts. Each teacher demonstrated unique approaches and varying levels of conceptual understanding, with some showing promise in constructivist strategies and contextual reasoning, while others struggled with scientific clarity and pedagogical confidence. This comparative overview provides a concise snapshot of how each teacher engaged with core astronomy topics, offering insight into the diversity of teaching practices and the specific support needed to enhance their pedagogical content knowledge (PCK). To ensure transparency and consistency in how the "areas for development" were identified, the teachers' explanations were analyzed using a set of clearly defined criteria.

These criteria focused on four key dimensions of conceptual understanding: scientific accuracy, referring to whether the explanation aligned with accepted astronomical principles; conceptual coherence, which considered the teacher's ability to correctly relate concepts such as rotation, revolution, axial tilt, seasons, and eclipses; scientific language and precision, assessing the degree of clarity and correctness in terminology used; and depth of reasoning, which evaluated whether the explanation moved beyond surface-level descriptions to demonstrate a more developed conceptual framework. These indicators guided the coding process and allowed for systematic differentiation between minor lapses in clarity and more substantive conceptual misunderstandings. The resulting "areas for development" summarized in Table 2 therefore reflect consistent patterns in the teachers' responses and highlight specific aspects of astronomical content knowledge that require further strengthening.

Table 2 indicates a comparative overview of individual teacher profiles, highlighting both instructional strengths and areas for development in teaching astronomical concepts. Several teachers, such as Mam

Table 2: Individual teacher profiles

Teacher	Strengths	Areas for development	Interview except examples
Mam Nandi	Creative teaching approach; linked seasons to revolution.	Misconceptions about eclipses; confused rotation with tilt; lacked scientific precision.	*Revolution is the travelling of the planet or the bodies because there are also the asteroids of bodies around the sun on their orbit, which is as simple as a path.*
Sir Lekos	Used gestures and visual aids; partial understanding of eclipses.	Simplistic explanations; confused rotation and revolution; omitted axial tilt.	*Revolution is the movement of Earth around the sun. When I was describing rotation I used the word "spinning," and then revolution is moving around something. Yes, the learners were able to understand the two concepts of rotation and revolution.*
Mam Maprezz	Strong conceptual grasp; contextualized explanations; integrated leap years.	Needs refinement in scientific language and clarity.	*Revolution occurred when the Earth moves around the sun for three hundred and sixty-five days (365) and six hours or a quarter day (1/4) in one year, which is 365 1/4 days. The moon revolves around the Earth for twenty-eight days (28) in one month, and the Earth rotates around its own axis for twenty-four hours (24 hrs) in one day. This rotation happens at an angle of 23.5° through the process called tilting.*
Sir Mase-mos	Proposed use of models; constructivist intent.	Tentative explanations; vague terminology; admitted lack of revision.	*Revolution eehh... eehh... I understand it as a concept that deals with circulation of things, things that come time and again and keep on coming back again. That is my basic understanding of the word revolution. And I understand that the Earth revolves around the sun, the sun is stable there, and other objects also revolve around the sun, which is why we say the sun is at the center of the solar system.*
Sir Thobs	Used improvised models; constructivist approach.	Lacked depth in explanations; misconceptions about eclipses.	*eish is it not related to the moon? Uummhh but I guess the one for the sun is by the time when the moon and the Earth are direct and the other one, I guess it happened once in my lifetime and it just closed the sun and then the sun became big dark, and the moon would have a shadow and we get an eclipse.*
Sir Maps	Attempted learner-centered strategies.	Confused axial tilt; vague eclipse explanations; misunderstood day/night cycle.	*The eclipse we talk of, where we see half of the moon being dark or the part of the sun being dark. Eish, I have not done revision of these eclipses, I forgot.*
Sir Choss	Enthusiastic; proposed hands-on activities.	Confused tilt with rotation; vague eclipse explanations.	*When you tilt neh! There is a pattern because you cannot divorce one from the other. There is an imaginary line i.e., axis. Let me come first to the sun: when we tilt it is like you spin, and there is this called imaginary line that cuts the Earth in between from the northern hemisphere and southern hemisphere. So when we tilt, uummhh when you spin neh! It is no longer movement we call revolution.*
Mam Seaps	Correctly linked rotation to day/night.	Hesitant delivery; conflated tilt and rotation; vague on eclipses and seasons.	*In terms of eclipse neh! Eish eehh... I have not revised that, but I think it is when the moon shows the dark side and when the sun is dim or dark because of the movement of the Earth in between.*
Sir Nkomos	Partial understanding of day/night.	Fragmented knowledge; lacked scientific terminology; confused eclipse types.	*Eclipse I am not sure that I am gonna say it correctly but, if the moon is on the other side and the sun is on the other side then the Earth is between them. Yah, let me start with the one when the Earth is between the moon and the sun. Ok, the lunar eclipse is when the Earth obstructs the moon, and when the Earth is also obstructing the sun, and both appear to be black or reddish in color.*
Sir Bops	Willingness to engage despite uncertainty.	Severe content gaps; lacked clarity and confidence.	*... even the eclipse I do not remember it very well. I guess lunar has to do with the moon, where the solar is relatively to the sun. Eish, those notions I forgot, and I guess they needed a thorough revision.*

Maprezz and Mam Nandi, demonstrated promising strengths in conceptual understanding and contextual reasoning, with Mam Maprezz notably integrating leap years into her explanations. Others, like Sir Thobs, Sir Masemos, and Sir Choss, showed constructivist intent through the use of models and hands-on activities, reflecting efforts to make abstract concepts more tangible. However, across the cohort, significant challenges were evident. Misconceptions about eclipses, confusion between rotation and axial tilt, and vague or hesitant explanations were recurring issues. Teachers such as Sir Maps, Sir Nkomos, and Sir Bops exhibited critical gaps in scientific clarity and pedagogical confidence, often compounded by limited content revision. The table underscores the need for targeted professional development to address both conceptual misunderstandings and instructional delivery, ensuring that teachers are equipped to support accurate and engaging astronomy education.

The analysis revealed three prominent challenges that hindered effective astronomy instruction across the teacher cohort (Table 2). First, conceptual confusion was widespread, with many teachers struggling to distinguish between rotation, revolution, and axial tilt—leading to inaccurate explanations of phenomena such as day and night or seasonal changes. Second, a lack of scientific precision was evident in the delivery of content; explanations were frequently vague, hesitant, or scientifically incorrect, which risks reinforcing misconceptions among learners. Third, gaps in pedagogical content knowledge (PCK) were apparent, as teachers often found it difficult to translate their understanding into clear, structured, and learner-friendly teaching strategies. These challenges collectively highlight the need for targeted professional development that strengthens both conceptual mastery and instructional competence in space science education.

5 Discussion

The cases of Mam Nandi, Sir Lekos, Mam Maprezz, Sir Masemos, Sir Thobs, Sir Maps, Sir Choss, Mam Seaps, Sir Nkomos, and Sir Bops collectively highlight the complexities and challenges science teachers face in teaching astronomical concepts. A common thread among these cases is the struggle with precision, clarity, and depth in explaining abstract concepts such as eclipses, axial tilt, rotation, and revolution. For instance, Mam Nandi and Sir Lekos demonstrated fundamental misunderstandings about eclipses, while Sir Maps and Sir Choss confused the causes of day and night, attributing them to Earth's tilting rather than rotation.

These cases reflect broader trends identified in recent literature. Dantic et al. (2024) found that pre-service science teachers hold persistent misconceptions about celestial phenomena, particularly eclipses and planetary motion. Yu et al. (2010) emphasized that such misconceptions are deeply ingrained and require deliberate instructional strategies to correct. Cox et al. (2016) further noted that teachers often lack awareness of student misconceptions and struggle to adapt instruction accordingly, a challenge mirrored in the fragmented and hesitant explanations given by Sir Nkomos and Mam Seaps.

The cases also reveal significant gaps in teachers' conceptual understanding, with many displaying uncertainty. Mam Seaps, for example, showed partial grasp of revolution but lacked confidence, using tentative language. Sir Bops's struggles were even more pronounced, admitting to not revising key concepts and guessing about the causes of lunar and solar eclipses. Sir Nkomo's responses reflected incomplete and loosely framed conceptual knowledge, with fragmented, hesitant, and imprecise explanations. These gaps in teacher knowledge can directly hinder learner's opportunities to develop accurate scientific understandings of complex natural phenomena.

Recent studies underscore the importance of pedagogical content knowledge (PCK) in addressing these challenges. Belayneh (2025) argues for a dual framework of general and topic-specific PCK (TSPCK), which is crucial for aligning instruction with student needs and digital fluency. Dragnić-Cindrić and Anderson (2025) found that pre-service teachers often develop uneven PCK, with strong teaching orientations but weak understanding of student cognition and assessment issues evident in the cases of Mam Seaps and Sir Nkomos. Nielsen (2014) suggests that integrating student feedback into lesson planning can enhance enacted PCK, helping teachers refine their instructional approaches.

The cases strongly support the necessity of targeted, topic-specific training programs to strengthen teachers' basic knowledge and instructional competence in space science topics. With continuous professional development, teachers like Mam Seaps, Sir Nkomos, and Sir Bops could improve their content mastery and confidence, enhancing their ability to engage learners and correct misconceptions. Rehman et al. (2025) advocate for such targeted professional development, emphasizing its role in addressing conceptual gaps and pedagogical inconsistencies.

By providing teachers with the necessary support and resources, they can develop confidence and expertise to provide accurate and engaging instruction, ultimately enhancing learner understanding and achievement in astronomy. Moreover, such support can help teachers move beyond mere transmission of facts and instead facilitate meaningful learning experiences that promote scientific literacy and critical thinking. The cases also highlight the importance of pedagogical content knowledge in teaching astronomy. Teachers need not only to possess a deep understanding of the subject matter but also to be able to convey complex concepts in a clear and concise manner. By focusing on both content knowledge and pedagogical skills, professional development programs can help teachers become more effective instructors and foster a deeper appreciation of astronomy among their learners (Belayneh, 2025).

The results of this study are consistent with existing research on teachers' understanding of astronomy concepts. The study's findings align with Frede's (2006) research, which suggests that teachers often hold non-scientific understandings of the astronomical concepts they teach. This is further supported by studies such as Kanli (2014), which found extensive misconceptions among pre-service and in-service science teachers about basic astronomy concepts like seasons, moon phases, and the sun's position. Similarly, Stears et al. (2011) reported limited conceptual change in teachers' understanding after a module, attributing this to ineffective instructional strategies. Sule and Jawkar (2019) also highlighted significant skill deficits in imparting correct astronomical knowledge due to information gaps and poor logical reasoning. These findings collectively suggest that teachers' misconceptions and skill deficits in astronomy are persistent issues that require targeted professional development and support. The current study's results reinforce the need for teachers to address these gaps in knowledge and understanding to improve the teaching and learning of astronomy.

The findings of this study highlight the significant challenges that science teachers face in developing a deep understanding of astronomical concepts, such as revolution, axial tilt, eclipses, and seasonal changes. These results are consistent with previous research that has shown that many teachers struggle to articulate clear and accurate explanations of complex scientific concepts (Kanli, 2014; Stears et al., 2011; Sule & Jawkar, 2019). Research consistently shows that many teachers struggle to clearly explain complex scientific concepts, particularly in astronomy. Studies have documented specific misconceptions among teachers, such as believing that seasons occur due to the Earth's distance from the Sun rather than its axial tilt, as found in a study of 45 secondary science teachers in Thailand where 42% held this misconception (Jansri & Ketpichainarong, 2020). This lack of understanding is not limited to secondary teachers, as primary teachers in Slovenia struggled with switching between heliocentric and geocentric systems and understanding frames of reference (Susman & Pavlin, 2020).

The findings of this study also underscore the importance of pedagogical content knowledge (PCK) in teaching astronomy. The teachers' ability to design effective instructional strategies and assessments depends on their understanding of the subject matter and their ability to communicate complex concepts in a clear and concise manner (Shulman, 1986). However, the results of this study suggest that many teachers lack the PCK needed to teach astronomy effectively, which can have a negative impact on learners' understanding and engagement with the subject.

The need for targeted professional development programs that focus on strengthening teachers' conceptual mastery and instructional confidence is clear. Research has shown that effective professional development programs can have a positive impact on teachers' knowledge and practices, leading to improved student outcomes (Desimone, 2009). However, to design such programs effectively, it is essential to first identify the specific misconceptions and gaps in teachers' understanding of key astronomical concepts—such as Earth's rotation, axial tilt, eclipses, seasonal shifts, day-night cycles, and planetary revolution—and examine how these shortcomings shape their instructional strategies. By investing in teacher support and development, teachers and policymakers can work together to improve science education and promote a deeper understanding of the natural world among learners.

6 Limitations of the study

While this case analysis provides valuable insights into science teachers' understanding and instructional approaches to astronomical concepts, several limitations must be acknowledged. First, the study draws on in-depth data from ten teachers; therefore, the findings are intended to provide contextualized insights rather than broad generalizations. Second, data were primarily derived from classroom observations and semi-structured interviews, which may be influenced by participant bias and performance anxiety. Third, the study did not include learner perspectives or achievement data, which could have provided a more comprehensive view of instructional impact. Additionally, variations in teaching experience, school resources, and curriculum exposure were not fully controlled, potentially affecting the consistency of findings. Future research could address these limitations by incorporating larger, more diverse samples, triangulating data sources, and examining learner outcomes alongside teacher practices.

7 Conclusion

Case analysis has illuminated the multifaceted challenges that Grade 7 Natural Sciences teachers encounter when teaching astronomical concepts. The study's central research question—examining misconceptions or gaps in teachers' conceptual understanding of Earth's rotation, axial tilt, eclipses, seasonal shifts, day–night cycles, and planetary revolution, and how these affect instructional strategies—was reflected in the findings. Based on the analysis of ten Grade 7 Natural Sciences teachers, some teachers across varying levels of experience demonstrated strengths in learner engagement and partial conceptual clarity; however, the majority faced challenges with scientific precision, pedagogical confidence, and effectively communicating abstract astronomical ideas. Recurring misconceptions, particularly around rotation, revolution, tilt, and eclipses, were evident among both early-career teachers and seasoned teachers with decades of practice. These findings underscore that teaching experience alone does not guarantee conceptual mastery, highlighting the urgent need for targeted, topic-specific professional development.

Importantly, the study also points to the significance of the range of subjects studied during the teacher education program. Because Natural Sciences is a broad learning area—encompassing life sciences, physical sciences, earth sciences, and technological content, the depth and balance of exposure teachers receive during training becomes critical. Many pre-service programs offer limited coursework in astronomy compared to other science domains, which may contribute to the persistent misconceptions identified in this study. Strengthening teacher preparation by ensuring that all major science strands, including astronomy, receive adequate conceptual and pedagogical attention would better equip teachers to navigate the interdisciplinary demands of the curriculum.

Strengthening teachers' pedagogical content knowledge (PCK), refining their use of scientific language, and equipping them with strategies to address learner misconceptions are essential steps toward improving astronomy education. By investing in continuous support and structured training, teachers and policymakers can ensure that teachers—regardless of career stage—are better prepared to foster accurate understanding, correct misconceptions, and inspire curiosity about space science among learners aged 12 to 13.

Ultimately, the study's findings carry significant implications for teacher education, professional development, and curriculum design. Prioritizing teacher knowledge, the breadth of subject exposure in pre-service programs, and instructional capacity will be vital in advancing science education and promoting a deeper, more accurate understanding of the natural world among learners.

References

Ampartzaki, M., Tassis, K., Kalogiannakis, M., Pavlidou, V., Christidis, K., Chatzoglidou, S., & Eleftherakis, G. (2024). Assessing the initial outcomes of a blended learning course for teachers facilitating astronomy activities for young children. *Education Sciences*, *14*(6), 606. https://doi.org/10.3390/educsci14060606

Ball, D. L., & McDiarmid, G. W. (1990). The subject-matter preparation of teachers. In R. R. Hawley & J. D. Hawley (Eds.), *The handbook of research on teacher education* (pp. 437–449). Macmillan. https://files.eric.ed.gov/fulltext/ED310084.pdf

Belayneh, K. D. (2025). Reframing pedagogical content knowledge and topic-specific pedagogical content knowledge as dual frameworks for teaching and learning. *Pedagogical Research*, *10*(3), Article em0247. https://doi.org/10.29333/pr/16854

Braun, V., & Clarke, V. (2021). *Thematic analysis: A practical guide*. Sage Publications.

Brinkmann, S., & Kvale, S. (2018). *Doing interviews*. Sage Publications. https://doi.org/10.4135/9781529716665

Burrows, A. C., Borowczak, M., Myers, A., Schwortz, A. C., & McKim, C. (2021). Integrated STEM for teacher professional learning and development: "I need time for practice". *Education Sciences*, *11*(1), 21. https://doi.org/10.3390/educsci11010021

Carli, M., Leonardi, A. M., Ciroi, S., & Pantano, O. (2025). Teaching physics through astronomy in secondary school: The Asiago Teachers' Network on Astrophysics. *Journal of Physics: Conference Series*, *2950*(1), 012034. https://doi.org/10.1088/1742-6596/2950/1/012034

Chi, M. T. H. (2013). Two kinds and four sub-types of misconceived knowledge, ways to change it, and the learning outcomes. In S. Vosniadou (Ed.), *International handbook of research on conceptual change* (2nd ed.) (pp. 49–70). Routledge. https://doi.org/10.4324/9780203154472.CH3

Cox, M., Steegen, A., & De Cock, M. (2016). How aware are teachers of students' misconceptions in astronomy? A qualitative analysis in Belgium. *Science Education International*, *27*(2), 277–300. https://files.eric.ed.gov/fulltext/EJ1104665.pdf

Creswell, J. W., & Poth, C. N. (2016). *Qualitative inquiry and research design: Choosing among five approaches.* SAGE publications.

Danaia, L., & McKinnon, D. (2007). Common alternative astronomical conceptions encountered in junior secondary science classes: Why is this so? *Astronomy Education Review*, *6*, 32–53. https://doi.org/10.3847/AER2007017

Dantic, M. J., Molnar, J. M. T., Alves, M. C., Calma, M., & Pascual, R. A. (2024). Misconceptions of the science education freshmen students towards astronomy. *Galaxy International Interdisciplinary Research Journal*, *12*(4). https://internationaljournals.co.in/index.php/giirj/article/view/5508

Dragnić-Cindrić, D., & Anderson, J. L. (2025). Developing pre-service teachers' pedagogical content knowledge: Lessons from a science methods class. *Education Sciences*, *15*(7), Article 860. https://doi.org/10.3390/educsci15070860

Desimone, L. M. (2009). Improving impact studies of teachers' professional development: Toward better conceptualizations and measures. *Educational Researcher*, *38*(3), 181–199. https://doi.org/10.3102/0013189X0833114

Frede, V. (2006). Pre-service elementary teacher's conceptions about astronomy. *Advances in Space Research*, *38*(10), 2237–2246. https://doi.org/10.1016/j.asr.2006.02.017

Govender, N. (2011). South African primary school teachers' scientific and indigenous conceptions of the Earth-Moon-Sun system. *African Journal of Research in Mathematics, Science and Technology Education*, *15*(2), 154–167. https://doi.org/10.1080/10288457.2011.10740709

Guerra-Reyes, F., Guerra-Dávila, E., Naranjo-Toro, M., Basantes-Andrade, A., & Guevara-Betancourt, S. (2024). Misconceptions in the learning of natural sciences: A systematic review. *Education Sciences*, *14*(5), 497. https://doi.org/10.3390/educsci14050497

Jansri, S., & Ketpichainarong, W. (2020). Investigating in-service science teachers' conceptions of astronomy, and determine the obstacles in teaching astronomy in Thailand. *International Journal of Educational Methodology*, *6*(4), 745–758. https://doi.org/10.12973/ijem.6.4.745

Kanli, U. (2014). A study on identifying the misconceptions of pre-service and in-service teachers about basic astronomy concepts. *Eurasia Journal of Mathematics, Science and Technology Education*, *10*(5), 471–479. https://doi.org/10.12973/eurasia.2014.1120a

Maree, K., & Pietersen, J. (2016). *First steps in research.* Van Schaik Publishers.

Marshall, C., & Rossman, G. B. (2016). *Designing qualitative research* (7th ed.). SAGE Publications.

Merriam, S. B. (1988). *Case study research in education: A qualitative approach.* Jossey-Bass.

Nasution, L. A., Khairiah, K., Siregar, J., Destini, R., Kurniawan, C., & Binti Rusli, R. (2025). Effectiveness of Stellarium application in enhancing student's understanding: Astronomy concepts in physics education. *Jurnal Eduscience*, *12*(4), 957–966. https://jurnal.ulb.ac.id/index.php/eduscience/article/view/7274

Nielsen, B. L. (2014). Students' annotated drawings as a mediating artefact in science teachers' professional development. *NorDiNa: Nordic Studies in Science Education*, *10*(2), 162–175. https://www.ucviden.dk/ws/portalfiles/portal/140188127/NorDiNa_annotated_drawings.pdf

Patton, M. Q. (2015). *Qualitative research and evaluation methods* (4th ed.). SAGE Publications. https://lccn.loc.gov/2014029195

Rehman, N., Huang, X., Mahmood, A., Zafeer, H. M. I., & Mohammad, N. K. (2025). Emerging trends and effective strategies in STEM teacher professional development: A systematic review. *Humanities and Social Sciences Communications*, *12*, 32. https://doi.org/10.1057/s41599-024-04272-y

Robinson, K. A., Saldanha, I. J., & McKoy, N. A. (2011). Development of a framework to identify research gaps from systematic reviews. *Journal of Clinical Epidemiology*, *64*(12), 1325–1330. https://doi.org/10.1016/j.jclinepi.2011.06.009

Rodrigues, L., Meneses, A., Montenegro, M., & Cortès, C. (2025). Direct and indirect opportunities to learn astronomy within the Chilean science curriculum. *International Journal of Science and Mathematics Education*, *23*(1), 161–191. https://doi.org/10.1007/s10763-024-10459-1

Salimpour, S., Fitzgerald, M., & Hollow, R. (2024). Examining the mismatch between the intended astronomy curriculum content, astronomical literacy, and the astronomical universe. *Physical Review Physics Education Research*, *20*. https://doi.org/10.1103/PhysRevPhysEducRes.20.010135

Şensoy, Ö., & Asana, Y. Y. (2025). Prospective teachers' interest in astronomy: The effect of conceptual change texts in astronomy. In Cheng-Yao Lin & Li Sun (Eds.), *Diversity, Equity, and Inclusion for Mathematics and Science Education: Cases and Perspectives* (pp. 97–144). IGI Global Scientific Publishing. https://doi.org/10.4018/979-8-3373-0345-1.ch004

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, *15*(2), 4–14. https://doi.org/10.3102/0013189X01500200

Slater, E. V., Morris, J. E., & McKinnon, D. (2018). Astronomy alternative conceptions in pre-adolescent students in Western Australia. *International Journal of Science Education*, *40*(17), 2158–2180. https://doi.org/10.1080/09500693.2018.1522014

Stears, M., James, A., & Good, M. A. (2011). Teachers as learners: A case study of teachers' understanding of astronomy concepts and processes in an ACE course. *South African Journal of Higher Education*, *25*(3), 568–582. https://hdl.handle.net/10520/EJC37690

Sule, A., & Jawkar, S. (2019). Teacher's misconception in curricular astronomy. In *EPJ Web of Conferences* (Vol. 200, p. 01012). EDP Sciences. https://doi.org/10.1051/epjconf/201920001012

Susman, K., & Pavlin, J. (2020). Improvements in teachers' knowledge and understanding of basic astronomy concepts through didactic games. *Journal of Baltic Science Education*, *19*(6), 1020–1033. https://www.ceeol.com/search/article-detail?id=944960

Vosniadou, S. (2020). Students' misconceptions and science education. In Li-fang Zhang (Ed.), *Oxford Research Encyclopedia of Education.* Oxford University Press. https://doi.org/10.1093/acrefore/9780190264093.013.965

Yin, R. K. (2012). A (very) brief refresher on the case study method. *Applications of case study research*, *3*, 3–20.

Yu, K. C., Sahami, K., & Denn, G. (2010). Student ideas about Kepler's laws and planetary orbital motions. *Astronomy Education Review*, *9*(1), 010108–010117. https://doi.org/10.3847/AER2009069