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Between astronomy and astrology: Preservice teachers' misconceptions about celestial objects

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Abstract. This article addresses the persistence of astronomical misconceptions among preservice teachers. The study makes two contributions: 1) an object-based classification framework is proposed (Stars & Constellations, Moon, Solar System, Sun), grounded in cognitive theory and aligned with standard curricula; 2) the prevalence of misconceptions is illustrated through survey data from 69 students at Herzen State Pedagogical University of Russia. The survey instrument is not psychometrically validated and serves to document a precedent rather than measure population-level prevalence. Results show that 68.1% of respondents conflate zodiac signs with astronomical constellations, and 42% agree with the notion of astrology as a 'gateway' to astronomy. Cognitive mechanisms underlying the myth persistence (naive theories, synthetic models, p-prims) are discussed, along with five pedagogical strategies for addressing misconceptions in teacher training.

Keywords: astronomical misconceptions, astrology, teacher training, pedagogical strategies, scientific literacy, misconception classification, cognitive mechanisms

Introduction

Astronomy has long been recognized as one of the most captivating subfields of physics, sparking immense fascination among learners across all age groups (Hennig et al. 2023). Due to this high level of interest, recent educational reforms in various countries, including Russia, have sought to strengthen the role of astronomy within the core school curriculum. However, a persistent problem remains: despite formal pedagogical efforts, astronomical misconceptions — alternative conceptions, children's ideas, naive beliefs, etc. — are unusually resistant to change (Sadler et al. 2009). These misconceptions are not merely isolated errors but deep-seated beliefs that contradict accepted scientific information (Comins 1998; Driver 1989).

This challenge extends beyond physics classrooms. In an era where pseudoscientific beliefs — such as astrology — are resurging in popularity, misconceptions about celestial phenomena are increasingly pervasive among educators of all disciplines.

Astrology, defined as a 'doctrine concerning the influence of the mutual positions of the planets, the Moon, and the Sun, as well as their locations against the background of bright stars in various constellations, on natural phenomena (such as rainfall, droughts, earthquakes, etc.) and on the destinies of individual people and entire nations' (Zhukov 2021, 60), is often conflated with astronomy in public discourse. While astronomy is a rigorous scientific discipline grounded in empirical evidence, astrology is widely regarded as a pseudoscience by the scientific community.

This conflation poses a significant challenge for secular education systems, which aim to foster scientific literacy and critical thinking while respecting diverse cultural beliefs.

The challenge is further complicated by the fact that not only preservice physics teachers but educators across disciplines — those responsible for guiding student conceptual development — often harbor the same misconceptions as their pupils (Hennig et al. 2023; Nandi et al. 2015; Parker, Heywood 1998). Research indicates a significant gap between a teacher's ability to perform formal tasks, such as ranking astronomical objects by size, and their ability to provide accurate qualitative explanations for celestial phenomena (Rajpaul et al. 2014). Moreover, teachers tend to dramatically overestimate student performance, largely because they remain unaware of the specific, entrenched misconceptions their students hold (Sadler et al. 2009). A classic illustration of this phenomenon is the documentary *A Private Universe*.

In this context, our study addresses the urgent need to equip educators with tools to distinguish scientific knowledge from pseudoscientific claims. We focus on the classification of astronomical misconceptions, with particular attention to the cultural and cognitive factors that perpetuate these myths.

This study makes two contributions: 1) it proposes an object-based classification framework for astronomical misconceptions, grounded in cognitive theory and aligned with standard curricula; 2) it illustrates the persistence of these misconceptions through survey data from 69 students (preservice teachers) at Herzen University. By proposing pedagogical strategies, we aim to support teachers in fostering a scientific worldview — one that embraces empirical inquiry while leaving questions of religious or metaphysical belief to personal conviction.

Illustrative pilot survey

This pilot survey serves as an illustrative case rather than a representative study. Its purpose is to demonstrate that astronomical misconceptions — particularly the conflation of astronomy and astrology — persist among preservice teachers across disciplines.

Survey design

To explore the prevalence of astronomical misconceptions among future educators, we conducted an anonymous online survey of 69 students (aged 17–28) from one pedagogical university, representing 17 academic programs across bachelor's and master's levels (Table).

Table. Distribution of survey participants by year and level of study (count of participants)

Field of study	Bachelor's level				Master's level	
	1st year	2nd year	3rd year	4th year	1st year	2nd year
Preschool and primary education	1	—	—	—	—	—
Special education	2	—	1	—	—	—
Foreign language teaching	—	1	3	—	—	—
Information technology and labor education	1	—	1	1	—	—
History and social sciences teaching	—	5	1	1	—	—
Theater and music arts education	1	—	—	—	—	—
Psychology	3	2	—	—	—	—
Physics	3	3	11	4	—	1
Physical education (Sports)	1	—	—	—	—	—
Philosophy education	—	—	—	—	—	1
Fine Art education	—	3	—	—	—	—
Economics and educational management	—	—	—	—	1	—
Life safety education	1	—	—	—	—	—
Mathematics teaching	5	1	—	—	—	—
Geography teaching	—	—	—	1	—	—
Philology	2	1	2	1	—	—
Law (Legal studies)	—	1	1	1	—	—

The survey was distributed through closed university chat groups to limit access to enrolled students only and prevent third-party responses. Participation was voluntary, and no incentives were offered. A preamble to the survey informed participants about the study's purpose, the anonymous nature of data collection, and their right to discontinue at any time. Completion of the survey was taken as implicit consent. No personally identifiable information was collected, and all data were aggregated for analysis.

The study was conducted with the approval of the department leadership. Given the minimal-risk nature of the survey (anonymous, non-sensitive educational topics) and the absence of vulnerable populations, formal institutional review board approval was not required under local guidelines at the time of data collection. However, we acknowledge this as a limitation.

The survey comprised 18 questions, including 3 demographic items (program, year, age) and 10 questions on astrological beliefs and astronomy knowledge.

In addition, students were asked an open-ended question: 'Are there people in your social circle who believe in astrology, numerology, or Tarot cards? (If yes, specify what they believe in and describe any instances from life when predictions came true.)'

At the end of the survey, students were given the opportunity to provide an open-ended response to the question: 'If you do not believe in astrology, where does your knowledge of it come from?'

The responses cited below include answers to these questions.

The full survey instrument (in Russian with English translations for international readers) has been deposited in the Zenodo repository (Krushelnitckii, Razboinikova 2026).

Key findings

Zodiac literacy and cultural ubiquity

All respondents identified their zodiac sign, reflecting the pervasive cultural penetration of astrological terminology. When asked whether they inquire about peers' zodiac signs, 75.4% in our sample answered affirmatively, with comments like:

— *'My parents are very compatible, so my mom thinks their zodiac signs played a part in making their marriage work.'* (B.Ed. 2nd-year student, History and social sciences teaching)

— *'It's more about general knowledge and being able to hold a conversation on almost any topic with just about anyone.'* (B.Ed. 4th-year student, Geography teaching)

This aligns with prior research on astrology's role as a social lubricant, but our data highlights its normalization among future teachers.

Blurred boundaries: Astronomy vs. astrology

A key misconception was revealed by the task: 'Match birth date periods with zodiac signs' and the follow-up question: 'When does the Sun pass through the constellation Aries?'

The task included a decoy date range resembling Cancer's zodiac period but actually corresponding to the Sun's passage through Gemini. This tested whether students distinguish astronomical constellations from astrological signs.

In our sample, 68.1% of respondents conflated the two, demonstrating persistent confusion:

— *'[I have] no knowledge of astrology at all. But I'm interested in the concept of tarot — it'd be cool to understand how the cards are chosen to determine a person's possible fate during a reading. But I don't take fortune-telling seriously. Oh, and I just happened to learn the zodiac signs. That's not astrology, right?'* (B.Ed. 2nd-year student, Philology)

This echoes Vosniadou's (Vosniadou 1994) 'synthetic models', where students merge scientific terms with pseudoscientific narratives.

Personal encounters with occult practices

Open-ended responses also revealed divergent attitudes toward astrology's legitimacy:

— *Endorsement*. A physics student (B.Ed. 2nd-year student) described their *'full natal chart reading'* as *'100% accurate to my personality'*, linking it to their astrological trust.

— *Skepticism*. A bachelor 1st-year student (Life Safety education) noted: *'I believe that astrology cannot be reliable, as we can take the date and time of birth as a starting point. Doctors record this time by rounding it off, whereas astrology requires precise timing for its calculations. Consequently, any conclusions drawn by astrology may fundamentally be incorrect.'* At the same time, she has friends in her social circle who are interested in tarot cards and astrology.

The Kepler paradox

When presented with Kepler's quote on astronomy's reliance on astrology for public appeal, 42% in our sample agreed, framing astrology as a 'gateway' to science:

— *'Astrology can be considered a science equal to astronomy.'* (B.Ed. 1st-year student, Physics)
— *'Astrology sparks people's interest in astronomy.'* (B.Ed. 3rd-year student, Foreign language teaching)
— *'...at present, astronomy as a science is capable of standing on its own due to people's awareness of the importance of space exploration. However, I agree with the idea that the serious branches of any science rely on an engaging presentation of its fundamentals, be it popular science or astrology.'* (B.Ed. 3rd-year student, Physics)
— *'I believe that astrology is scientifically flawed, but at the same time it helps the development of astronomy.'* (B.Ed. 3rd-year student, Physics)

These responses illustrate a paradoxical relationship between astrology and astronomy in the eyes of preservice teachers. Some participants — including physics students — view astrology as a catalyst for public interest in science, echoing Kepler's historical observation about its role in sustaining astronomy's appeal. Their comments reveal a pragmatic stance: astrology, despite its scientific flaws, is perceived as a cultural bridge that can engage audiences who might otherwise disregard astronomy.

While our small-scale data precludes generalization, it establishes a precedent: future teachers, regardless of the discipline, may actively endorse pseudoscientific beliefs. This finding aligns with prior Russian research documenting similar patterns of astronomical misconceptions among preservice teachers at pedagogical universities (Nandi et al. 2015).

These misconceptions are particularly concerning among preservice teachers, whose future students may inherit these blurred boundaries. As prior research indicates (Comins 2001; Vosniadou 1994), such synthetic models — where scientific and nonscientific ideas coexist — can hinder the development of a coherent scientific worldview.

Limitations

Several methodological limitations should be acknowledged.

First, the sample size (69 participants) and single-institution design limit statistical power and generalizability. The voluntary nature of participation may have introduced self-selection bias, as students with stronger opinions on astrology — either positive or negative — may have been more likely to complete the survey.

Second, the open-ended responses were analyzed thematically without formal intercoder reliability procedures, as the number of substantive responses was limited. Third, all data are self-reported, which may be subject to social desirability bias, particularly on questions about belief in pseudoscience. Finally, the cross-sectional design precludes causal inferences about how misconceptions develop or change over the course of teacher training.

Third, the survey questions were designed to illustrate the persistence of astronomical misconceptions rather than measure their prevalence. The instrument was not validated psychometrically; its purpose was to document concrete examples of misconception patterns among preservice teachers.

Despite these limitations, this pilot study provides preliminary insights into the persistence of astronomical misconceptions among preservice teachers across disciplines — a population underrepresented in the existing literature. The findings should be interpreted as exploratory rather than definitive, and future research with larger, multi-institutional samples is recommended to validate these patterns.

Thus, astronomical misconceptions persist among preservice teachers across disciplines, but why do these beliefs prove so resistant to formal instruction? The following section examines the cognitive and cultural mechanisms that sustain these myths.

Why myths persist

These empirical findings raise a critical question: why do astronomical misconceptions persist despite formal education? The answer lies in cognitive and cultural mechanisms that sustain these beliefs.

Research in cognitive development suggests that individuals begin constructing a 'naive framework theory of physics' during infancy based on their everyday observations (Driver 1989; Piaget 1929; Vosniadou 1994). These early-formed intuitions often persist into adulthood, resisting modification even through formal scientific instruction.

The persistence of these myths can be attributed to several key factors.

a) The formation of 'synthetic models'. When students encounter scientific facts that contradict their framework theories (e. g., 'the Earth is a sphere'), they often attempt to reconcile the two views rather than abandoning their initial beliefs. This leads to the creation of hybrid or synthetic models, such as the 'hollow Earth' model, where people are imagined to live on a flat surface inside a spherical shell to avoid falling 'down'.

b) Phenomenological primitives. Students often rely on simplified cognitive scripts known as p-prims, which are superficial interpretations of reality. A primary example is the 'closer means stronger' p-prim; this intuitive 'common sense' leads many to conclude that the Earth is hotter in the summer because it is closer to the Sun, ignoring the role of axial tilt (Comins 1998; 2001).

c) Influence of media and science fiction. Popular culture is a major external source of astronomical errors. Cartoons often portray physically implausible events that damage students' intuitions. Similarly, science fiction movies and TV-series, for example, frequently depict the asteroid belt as a densely packed region requiring complex maneuvering, whereas in reality, asteroids are separated by millions of kilometers.

d) Vernacular misconceptions. These arise from the use of words that have one meaning in everyday language and another in a scientific context (e. g., the words 'work', 'weight', 'energy', etc.). This, for instance, leads to difficulties in understanding scientific terms such as 'shooting star' (used for meteors) or the 'dark side of the Moon' (which implies it is never illuminated).

e) Personal cosmology and sensory misinterpretation. Most people develop a 'personal cosmology' to explain the origins and motions of the universe (Comins 1998; Piaget 1929). Since our senses pre-filter information (for instance, the Sun appears yellow and seems to orbit a flat Earth), these uncritical interpretations are accepted as facts. Once a belief is incorporated into one's world view, individuals will go to extraordinary lengths to distort new facts to fit their existing beliefs.

In summary, astronomical myths are not simply a lack of knowledge but are coherent, internally consistent systems of explanation. Overcoming them requires more than just 'giving the right answer'; it requires the development of metaconceptual awareness, where learners begin to treat their beliefs as falsifiable hypotheses rather than unquestionable truths.

These cognitive and cultural factors explain why astronomical misconceptions prove resistant to traditional instruction. To translate this understanding into practice, educators need a structured tool to map specific misconceptions to observable phenomena. The following section presents such an object-based classification.

Object-based classification of astronomical misconceptions

Our classification of astronomical misconceptions integrates findings from academic literature, Millar's lists of students' misconceptions in physics (can be found at iop.org), and public science communication sources including blogs, podcasts, and documentaries. This synthesis reveals persistent patterns of misunderstanding that arise from the interplay between naive realism, gaps in physical knowledge, and cultural inertia.

We organize these misconceptions according to specific celestial objects — Stars and Constellations, the Moon, the Solar System, and the Sun — rather than abstract themes. This object-based approach was selected for its pedagogical alignment with standard astronomy curricula, its reflection of how learners cognitively structure celestial phenomena, and its capacity to address culturally specific myths associated with particular astronomical bodies.

Unlike previous topic-based classifications such as Comins', our framework grounds misconceptions in observable celestial objects, thereby facilitating more targeted educational interventions.

This classification framework focuses on observable celestial objects covered in standard school curricula. Misconceptions about specialized astrophysical objects (e. g., black holes, neutron stars) were intentionally excluded, as these topics are typically addressed at advanced levels. Future research may extend this framework to include such concepts.

Stars and Constellations

Misconceptions in this category are often driven by 'naive realism', where the sky is perceived as a solid dome and stars as burning points on a flat surface. Key errors include the following:

a) Physical nature. Stars are misunderstood as burning objects (ignoring thermonuclear fusion) or as 'falling' during meteor showers.

b) Spatial geometry. Constellations are incorrectly viewed as real, physical 3D groupings rather than arbitrary 2D regions of the sky.

c) Astrological influence. A persistent belief that celestial configurations mystically influence human destiny, supported by cognitive biases like the Barnum–Forer effect and the search for patterns in random data (apophenia).

We see the causes of these misconceptions in the historical roots of the animistic view of the sky, the persistence of naive realism, and the lack of understanding of stellar physics.

The Moon

Lunar myths are categorized by their perceived impact on human life and history.

a) Influence on behavior and health. The belief that full moons trigger insomnia, crime, or psychiatric disorders, often misapplying the Moon's gravitational effect on tides to the water in the human body.

b) Conspiracy theories. The 'Moon Hoax' myth, claiming the Apollo landings were fabricated. This arises from a misunderstanding of lunar physical conditions (e. g., shadows and lack of atmosphere) and a postmodern distrust of government institutions.

c) Everyday superstitions. Domestic myths where lunar phases are thought to dictate the timing of haircuts, agricultural work, or major life decisions.

Among the key causes of these misconceptions are illusory correlations, the influence of expectation effects, and insufficient understanding of gravitational physics.

The Solar System

This category covers misconceptions about planetary mechanics and characteristics.

a) The 'Planet Parade'. Alignments are misinterpreted as physical straight lines that exert catastrophic gravitational forces on Earth rather than simple optical phenomena.

b) The inner planets. Common errors include believing Mercury is the hottest planet due to its proximity to the Sun (in reality, Mercury's negligible atmosphere cannot retain heat, leading to extreme temperature fluctuations) and perceiving the asteroid belt as a dense, impassable field of rocks rather than a mostly empty space.

c) The outer planets. Jupiter is often mislabeled as a 'failed star', and Saturn's rings are incorrectly imagined as solid, monolithic disks.

d) Exoplanets and life. An anthropocentric bias that leads to the belief that habitable planets must be identical 'second Earths' and that life only exists in complex, intelligent forms.

We can attribute these misconceptions to the following factors: flawed extrapolation techniques; over-reliance on analogical thinking; the shaping effect of media imagery on public perception.

The Sun

Misconceptions about our star involve its physical nature and interaction with Earth.

a) Physical nature and the Sun's motion. Relics of geocentric thinking still suggest the Sun 'rises' or rotates around Earth. Its heat is often wrongly attributed to literal fire rather than plasma processes.

b) Influence on health and tech. The belief in a direct, deterministic link between every 'magnetic storm' and individual physical ailments (like headaches), as well as the myth that tanning is 'unconditionally healthy' while ignoring the risks of UV radiation.

These misconceptions stem from everyday sensory experience, false analogies, and ingrained linguistic patterns. The persistence of these barriers is driven not just by missing facts, but by imprecise language (like calling the Sun 'burning') and cognitive biases favoring simple explanations over scientific complexity.

This classification framework provides educators with a structured tool to map specific misconceptions to observable celestial objects. However, identifying misconceptions is only the first step. The following section outlines evidence-based pedagogical strategies for addressing each category within teacher training programs.

Implications for teacher training

Astronomy presents unique pedagogical challenges due to the nature of its subject matter. The phenomena it studies are typically inaccessible to direct experimentation, requiring instead prolonged observation of a megaworld where space and time are fundamentally interconnected. Astronomical processes occurring on timescales are either too slow or too rapid for immediate perception, further complicated by the specific wavelengths at which these phenomena manifest (Zhukov et al. 1997).

To effectively address these pedagogical challenges, teacher training in modern science concepts — particularly astronomy — must transcend traditional fact-based instruction. Merely presenting accurate information fails to dislodge deeply held naive models; instead, students frequently merge new scientific facts with preexisting misconceptions, creating hybridized understandings (e. g., a disk-shaped Earth model). True conceptual transformation requires integrating the following instructional strategies into teacher preparation programs.

The five strategies outlined below correspond to the misconception categories from Section 3. For instance, 3D modeling addresses spatial geometry errors (Section 3.1b, 3.3), while 'what if?' questions challenge causal misconceptions about lunar and solar influence (Section 3.2a, 3.4b).

a) Development of pedagogical content knowledge. Effective teaching requires more than just subject matter knowledge; teachers must possess an in-depth understanding of how students represent abstract ideas that do not resonate with their daily experience (Loyola, Vanegas-Ortega 2021; Parker, Heywood 1998). A key measure of Pedagogical Content Knowledge is a teacher's ability to identify the most popular 'distractors' or wrong answers, which allows them to address entrenched misconceptions directly rather than assuming students are 'blank slates' (Sadler et al. 2009). By understanding the specific origins of myths — such as media influence, language imprecision, or 'common sense' p-prims — teachers can help students think more critically (Comins 1998).

b) Practical 3D modeling. A major barrier is the difficulty of translating 2D textbook diagrams into 3D relative motions (Parker, Heywood 1998; Zhukov et al. 1997). Practical modeling, such as using polystyrene spheres and torches to simulate the Earth–Moon–Sun system, is paramount for learners to clarify and articulate their ideas (Baxter 1989; Parker, Heywood 1998). Such hands-on discovery makes the invalidity of naive beliefs visible in a way that lectures cannot.

c) Predictive 'what if?' questions. Teachers should utilize 'what if?' scenarios to follow misconceptions to their logical (and often absurd) contradictions (Comins 1998). For instance, asking what would happen to the Earth's orbit if its mass changed helps students realize that mass does not affect orbital motion, proving their intuitive 'heavier means faster' models incorrect (Comins 2001).

d) Peer discussion and verbalization. Encouraging students to share their explanations and defend them against criticism helps them compare personal models with scientific ones (Baxter 1989; Vosniadou 1994). Peer-led discussions transform the classroom from passive listening to active engagement, which has been shown to help even students with weaker backgrounds perform significantly better (Baxter 1989; Parker, Heywood 1998).

e) Historical parallels. Referring to historical ideas, such as the geocentric system, can make students feel more comfortable by showing that their naive notions were once the accepted scientific view (Baxter 1989). This highlights the tentative nature of science and the types of evidence required to change a theory.

Together, these strategies provide a practical toolkit for addressing the specific misconception categories identified in this study. Implementation within teacher training programs can help future educators recognize and correct these persistent errors in their own understanding before entering the classroom.

Conclusion

The documented cases of astronomical misconceptions among preservice teachers in our sample illustrate a potential gap in teacher training. Further research is needed to determine the prevalence of these patterns. Existing literature suggests that high academic achievement does not automatically eliminate naive framework theories established in childhood.

The categorization of misconceptions provided in our study is a vital tool for the development of Pedagogical Content Knowledge. Teacher education must focus on the processes of conceptual acquisition, making teachers explicitly aware of the specific misconceptions they will encounter in the classroom.

Future research with larger, multi-institutional samples is recommended to validate the proposed classification framework and test the effectiveness of the pedagogical strategies outlined herein.

Ultimately, the goal of physics education is to foster a 'metaconceptual awareness' that allows learners to distinguish between appearance and reality (Vosniadou 1994). By directly addressing the roots of incorrect beliefs — such as the confusion between the solar system and the galaxy or the 'no gravity in space' myth — educators can help students move toward a coherent, scientific worldview.

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Overcoming these misconceptions is the first step in freeing the mind, allowing individuals to understand how the natural world truly operates and to use that knowledge to make informed decisions.

A final thought

One respondent captured this nuanced relationship with astrology: '*I consider astrology a tool for self-reflection. People want to feel special, with unique characteristics. When we read a horoscope, we note traits that resemble us and criticize what doesn't apply. I don't believe in predictions, but I know my friends' zodiac signs. It's simply a curious way to learn more about yourself.*' (B.Ed. 1st-year student, Psychology)

This perspective serves as one example of how astrology can occupy a space between belief and curiosity — a psychological tool rather than a scientific claim. Understanding this distinction is essential for educators seeking to foster scientific literacy without dismissing the human need for meaning and self-understanding.

Conflict of Interest

The authors declare that there is no conflict of interest, either existing or potential.

Author Contributions

All authors contributed equally to this work. A. N. Krushelnitckii: conceptualization, theoretical framework, methodology supervision, manuscript writing, and final approval. T. D. Razboinikova: survey design, data collection and analysis, development of the object-based misconception classification. A. I. Kolesnikova: literature review, manuscript editing and formatting.

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