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ARTIGO ORIGINAL

Didactic-methodological approaches of teachers in training when discussing the shape of the Earth with Elementary School students

A conduta didático-metodológica de professores em formação na discussão sobre a forma da Terra com alunos do Ensino Fundamental

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Abstract: People's perceptions of the shape of the Earth are discussed extensively, but little is said about how teachers approach this subject. In this research, we seek to gain insight into the pedagogical and methodological strategies that aspiring educators envisage for teaching about this topic. Drawing from Harres' research, we devised and implemented a questionnaire in which each participant shared instructional and methodological approaches based on their perception of a hypothetical student's response about the Earth's shape. The findings suggest that the respondents have a pre-existing awareness of the students' perspectives on the matter. Differences between the two groups that came up highlight the significance of pedagogical debates in training future teachers.

Keywords: Elementary school; Astronomy education; Shape of the Earth; Teacher training.

Resumo: Atualmente, muito se diz sobre as percepções dos indivíduos acerca do formato da Terra, mas pouco sobre a postura de professores frente a tais questionamentos. Nesta pesquisa, buscamos compreender as estratégias didático-metodológicas vislumbradas por futuros professores sobre conteúdos acerca da forma da Terra. A partir da pesquisa de Harres, adaptamos e aplicamos um questionário, propondo uma simulação onde cada participante expôs a sua conduta didático-metodológica referente à sua percepção da resposta do aluno acerca da forma da Terra. Os resultados indicam que os participantes já apresentam reflexão sobre as ideias dos alunos sobre tal questão, há diferenças entre os dois grupos analisados, as quais indicam a importância dos debates pedagógicos na formação do futuro professor.

Palavras-chave: Ensino fundamental; Educação em astronomia; Forma da Terra; Formação de professores.

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Introduction

Currently, there is a prevalent discourse on the belief that our planet is not spherically shaped. The Flat Earth theory has garnered a significant following and has emerged as a noteworthy phenomenon that has piqued the interest of researchers in the fields of education and astronomy pedagogy. This phenomenon is not isolated (PIVARO, 2019) nor recent (ALBUQUERQUE; QUINAN, 2019), as it encompasses various issues pertaining to the scientific knowledge of Astronomy (OLIVEIRA, 2021).

Harres (2001) discussed the initial and continuous education of Brazilian teachers regarding the shape of our planet. Following a period of over two decades, we have implemented a modified iteration of the questionnaire developed by the author during his bachelor's coursework and research endeavor to examine the resemblances and disparities between contemporary and past approaches to the training of prospective Science teachers.

This paper reflects our thoughts on the outcomes of using this questionnaire. Our objective was to gain insight into the didactic-methodological approaches employed by teachers in training at the undergraduate level with respect to the subject matter of the Earth's shape. Our study also explored the perspectives of educators on students' understanding of the Earth's shape. In contrast to Harres' (2001) original objective, our inquiry does not aim to assess the development of educators' professional expertise. Nevertheless, our findings do present certain indications that suggest such an evolution may have occurred.

The following is a presentation of the theoretical framework that supports our research, with particular emphasis on the construction of knowledge pertaining to the Earth's shape. The inquiry also included an examination of the preparatory and continuous pedagogical training of teachers of science concerning the domain of Astronomy.

The historical trajectory of knowledge about the shape of the Earth

Given the well-established nature of human understanding of the Earth's shape, it appears that this topic could be considered relatively trivial. However, as indicated by the findings of our investigation, pre-service teachers are still required to confront this essential question.

The claim that the Earth was not the center of the cosmos was a result of:

> [...] the collapse of one of the firmest foundations on which the ancient and medieval conception of the world was based on, and which meant that this conception did not undergo important modifications for many, many centuries (BAIG; AGUSTENCH, 1987, p. 11).

However, as Kuhn (2002) points out, this radical shift was only feasible by upending a conceptual foundation based on Earth as the center of the universe. Prior to this, ancient Greek scholars had utilized astronomical observations from Babylonian and Egyptian sources to build explanatory models aimed at comprehending the motions of celestial entities.

Knowing the history of astronomy helps us comprehend its teaching and, more significantly, its learning, as Piaget and García (2011) noted when analyzing the importance of history of science in understanding children's cognitive development. Thus, we believe that a comprehensive understanding of astronomical phenomena and the shape of the Earth requires a profound spatial awareness that enables individuals to extract information from objects and apply it to an entirely *abstract* realm. Understanding the Earth as a *loose*

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celestial object in space can be a challenging task as it requires a sophisticated dissociation between our cosmic position and our terrestrial location. Moreover, it is essential to consider the students' prior knowledge when teaching about the shape of the Earth.

Leite and Hosoume (2007) state that, to comprehend the intricate spatial representation of seasonal changes, for example, it is imperative to acknowledge both the Earth's axial tilt and its movement around the Sun. Piaget (apud OLIVEIRA, 2005, p. 110, our translation) understands that spatial notions are not only developed through perception, but also "engendered from a series of actions and operations". As Piaget and Inhelder (1993, p. 474, our translation) put it,

> This is how topological relations, first, and projective and Euclidean relations, later, presuppose a rising number of increasingly complex coordination between actions, implying the determination of a line, of an angle, of parallels, of coordinates, etc., something beyond a simple finding, but such finding is part of a precise adjustment of the actions among themselves.

According to Piaget's (1949) perspective, the answer to this important question about the construction of space can be found in the functional interaction between operative and figurative structures. In other words, since the sensory-motor stage, individuals have been constructing spatial relations with their surroundings. According to Leite and Hosoume (2007, p. 34, our translation), "[...] The coordination of different points of view is a fundamental factor in the construction of spatial concepts". Thus, "[...] to understand the Sun as spherical or the sphericity of the planet Earth, one will need knowledge about movements, shadow analysis, or even belief in photographs taken from space." (LEITE; HOSOUME, 2007, p. 46, our translation).

Because celestial objects are "[...] things too big and far away from us for our mind to contain" (CASATI, 2001, p. 83, our translation). In essence, these entities are of such significant magnitude, yet so distant, that they *become invisible* for the human eye. Our understanding of complex concepts often relies on the use of approximations – this is how we become more *intimate* with the *secrets* of the sky. Our comprehension of outer space objects is not solely dependent on our visual perception, but also on our cognitive perception, which involves the mental reconstruction of these objects. This representation of objects, which we build by successive abstractions, allows us to know the world around us (SILVA *et al*., 2014).

The flat Earth theory's impact on science teaching

Para tanto, realizou-se uma pesquisa quantitativa com delineamento quase-experimental, na qual foi aplicado, como pré-teste e pós-teste, o Force Concept Inventory (FCI), a fim de coletar dados sobre as concepções não-newtonianas dos alunos.

Pivaro (2019) carried out a study about the online Flat Earth movement and found the following excerpt on the Flat Earth Society's (FES) official website:

> The evidence for a flat Earth is derived from many different facets of science and philosophy. The simplest is to rely on our own senses to discern the true nature of the world around us. The world looks flat, the background of clouds is flat, the movement of the sun; these are all examples that your senses are telling you that we do not live in a spherical heliocentric world (PIVARO, 2019, p. 4, our translation).

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In addition, the website discusses the alleged global conspiracy in which space travel agencies deceive the public with fake travels and records. According to Pivaro (2019, p. 4, our translation), this way of thinking involves the pursuit of "an abstraction by observing the immediate concrete". This reduces phenomena to what our senses can or cannot perceive. We can draw an inference from this phenomenon with epistemologists' extensive refutation of naive inductivism (CHALMERS, 1993).

As Silveira (2017, p. 4, our translation) points out:

> Since ancient Greece, according to, for example, Aristotle (384 BC - 322 BC) and, earlier, Pythagoras (570 BC - 495 BC), it is known that the Earth is (almost) spherical, and it is also well known that in the 3rd century BC Eratosthenes (276 BC - 194 BC) made the first determination of the Earth's circumference.

Even among Middle Age astronomers, including geocentrists, there were no doubts regarding the shape of our planet (SILVEIRA, 2017). "The Earth's geometry was essentially the same, whether in the old geocentric conception or in the revolutionary heliostatic conception that Copernicus revived in the 16th century" (SILVEIRA, 2017, p. 5, our translation). How then can we account for the surge in serious debate about the shape of our planet in the 21st century?

For Silveira (2017, p. 8, our translation):

> The resurrection – already in the 19th century – of the anachronistic concept of a Flat Earth, a concept that has been around since remote times in pre-scientific societies (in China, it prevailed until the 17th century), is due to Samuel Rowbotham (1816-1885).

Rowbotham (1865 apud SILVEIRA, 2017, p. 8, our translation) stated that he "[...] developed the Flat Earth concept, supposedly presenting experimental results to prove it". Without delving into the merits of his work, we would like to direct our readers to Silveira's research for further insights into the Flat Earth arguments and their alleged evidence.

Still on this topic, in Bezerra's essay (2020), a significant inquiry is raised concerning the prevalence of denialism and the rise of neoconservative factions that support the Flat Earth theory. According to the author:

> Mainly because the Flat Earth belief is only one symptom of a larger and very popular phenomenon in Brazil: the wave of scientific denialism, which I like to affectionately and metonymically call 'terraplanismo' [flat-earthism, in Portuguese], that is spreading throughout different knowledge areas. A wave that can be a deadly tsunami, as the tragic numbers among us of the COVID-19 pandemic attests (BEZERRA, 2020, p. 21, our translation).

As information has become more readily available, it is evident that this symptom can indicate a more complex, difficult-to-address situation that is assuming new proportions. There are, in our opinion, three situations to consider. The first is the quantity and velocity with which information circulates via social media and the internet. A condensed version of every topic is created just to be rapidly absorbed in various media formats. The second is that, as clinical studies in cognitive psychology and neuroscience have shown (ANDRADE; PRADO, 2003), our brain has adapted to a *hunter-gatherer* lifestyle:

> This preparation produces some functional characteristics, such as the use of mental shortcuts [...] related to an intuitive reasoning about the world. Therefore, something that seems right, from an intuitive point of view, has a great chance of structuring a belief and being considered correct even when there is evidence against it. This is one reason why pseudoscientific beliefs have so much appeal (PILATI, 2020, p. 66, our translation).

Thus, in terms of cognition, the notion of a flat Earth is congruent and aligns with the cognitive process that the human brain is evolutionarily predisposed to experience. Furthermore, it is commonly understood that beliefs precede their justification (SHERMER, 2012 apud PILATI, 2020, p. 67).

So, what does the state of science education look like in this context? Jiménez-Taracido and Otero (2019) examine the nuances of scientific thinking and its potential constraints within educational institutions. Here we reach the third situation concerning this symptom associated with denialist theories: the importance of formal education in fostering scientific thinking, or even scientific literacy.

Jiménez-Taracido and Otero (2019) define critical thinking as the kind of thinking in which it is possible to evaluate statements and arguments, establishing criteria of clarity and precision. For the authors:

> What we refer to as anti-critical thinking is responsible for promoting products that violate these criteria by deliberately seeking obscurity and imprecision. Students and citizens with a critical thinking education should be able to adversely evaluate these products (JIMÉNEZ-TARACIDO; OTERO, 2019, p. 120, our translation).

The authors also present some characteristics of anti-critical thinking widely used in marketing situations, loan agreements, etc. It is about the imprecision of language in the context of everyday life. They propose that such arguments can be used to explain the characteristics of anti-critical thinking in science classes, as it is a skill that can be taught to students so that they recognize it while studying science.

Despite the abundance of scientific evidence supporting the spherical shape of the Earth, there is still enough space for other theories, such as the Flat Earth theory. However, these theories may indicate that demonstrate that the field of education, particularly in astronomy, requires further focus and attention. Here are some thoughts on the training of science teachers and their interactions with astronomy-related subjects.

Science teachers' preparation for teaching Astronomy subjects

For years, several investigations on science teachers' higher education regarding astronomy-related topics have been carried out to analyze their knowledge in the field (BARTELMEBS, 2012, 2016; BRETONES, 1999; IACHEL, 2013, LANGHI, 2009; LANGHI; NARDI, 2012; LEITE, 2002; PEREIRA; VILAÇA; RODRIGUES, 2013; PRADO 2019; SILVA; LANGHI, 2021). In general, there is a gap in their preparation, as science teachers do not have adequate initial training to work with astronomy.

In Harres' study (2001), a survey was conducted among teachers in initial and continuing education to examine their classroom practices in relation to students' prior knowledge of the Earth's shape. In addition, the research assessed the possibility of a conceptual transformation of pedagogical approaches. The findings indicate that a subset of educators acknowledged the prior knowledge of their pupils, with a greater proportion of participants in more advanced instructional programs exhibiting such recognition.

However, the development of pedagogical strategies did not make the same progress, remaining remarkably inefficient.

Langhi and Nardi (2005) conducted an exploratory study with the goal of incorporating Astronomy topics into the early stages of elementary school teacher education, with a focus on addressing their difficulties. An investigation using semi-structured interviews was conducted to gain insight into what educators should know and do when teaching astronomy topics. The findings indicate various challenges in teaching astronomy, including personal and methodological obstacles, as well as problems regarding training and infrastructure. Additional challenges related to the sources of information that teachers have had access to were also identified.

Leite and Hosoume (2007) conducted a survey with elementary school science teachers to analyze their perspectives on astronomy topics. The study involved conducting semi-structured interviews to map individuals' understanding of the shapes and sizes of celestial bodies such as the Earth, Moon, and other planets, or the Sun and other stars, as well as their understanding of the sky and the universe. The results showed that an overwhelming majority of the teachers perceive space to be above the Earth. Others pointed out that Sun and stars are not equivalent, as the sun is hot, and the stars are cold. Based on these findings, we can verify that there is a significant demand for teachers' continuing education programs regarding astronomy topics, especially when they are a key component of Brazilian *Common Core* Standards.

Batista (2016) engaged in an exploratory study and qualitative analysis of teachers enrolled in initial and continuing education programs regarding the characteristics and bases that guide their instruction on astronomy topics. The analysis was conducted on the syllabi and curriculum requirements of courses in Science Teaching Methodology, and it was determined that they prioritize the methodological aspects of teaching. As a result, it leaves a gap when compared to certain Natural Sciences contents, which can sometimes lead to a separation between teaching practice and the student's context.

Training new teachers on how to effectively teach Astronomy in the classroom remains a challenge. One reason teachers may have a *dogmatic* approach to teaching about the shape of the Earth could be due to inadequate training in this area. Since teachers' arguments may not yet be consolidated enough for them to express confidence when discussing such topics in the classroom, their discourse is limited to the mere reproduction of concepts. Thus, a spark of distrust arises, which social media and the internet quickly turn into a raging bonfire via conspiracy pages, preventing the possibility of a critical view of reality.

Next, we will cover the data collection and analysis methodology in relation to pre-service educators' didactic-methodological recommendations for approaching the shape of the Earth.

Methodology

This study was based on a qualitative research approach (BOGDAN; BIKLEN, 1994). We considered Harres' (2001, p. 282) study as a model to elaborate a questionnaire, in the format of an online form, adapting the hypothetical situation presented below:

> The teacher in a science class asks the following question: If you were to keep walking in a straight line through the Earth's surface, what would happen? A student then answers:
> – After walking for a while, I would reach the end of the Earth's surface and, if I kept going, I would fall into an empty space (HARRES, 2001, p. 282, our translation).

Based on this, research participants were invited to answer to two open-ended questions: (a) What do you think about this student's response? (b) What teaching strategies would you recommend in this situation?

All participants are undergraduate students pursuing a degree in Biological or Exact Sciences with a teaching certificate at a Federal Institution of Higher Education and are thus pre-service teachers who will work with astronomy topics in their classes.

Data were collected using Google Forms, which generates a link to be distributed via email and social media. All participants declared they agreed to participate in this study if their anonymity was maintained. Accordingly, they remained anonymous during data collection and analysis.

Data analysis

Data analysis was performed by the Content Analysis method proposed by Bardin (2016). According to the author, content analysis is:

> [...] a set of communication analysis techniques that aim to obtain, through systematic and objective procedures for describing the content of messages, indicators (quantitative or not) that allow the inference of knowledge regarding the conditions of production/reception of these messages (BARDIN, 2016, p. 42, our translation).

Initially, we focused on constructing our analytical corpus, comprising the data gathered through the web-based survey. Subsequently, we transcribed the entire dataset into a single document.

To verify if there was a significant difference in their answers, we divided both Biological and Exact Sciences students (LCB and LCE respectively, acronyms in Portuguese for Licenciandos de Ciências Biológicas/Ciências Exatas) into two subgroups: first-year students and final-year students (represented by the numbers 1 and 4). **Table 1** shows the codes assigned to each participant, where the individual code of the student's response is represented by X in this instance, although we assigned a number to each LCE (01, 02…) and LCB (a1, a2…) student.

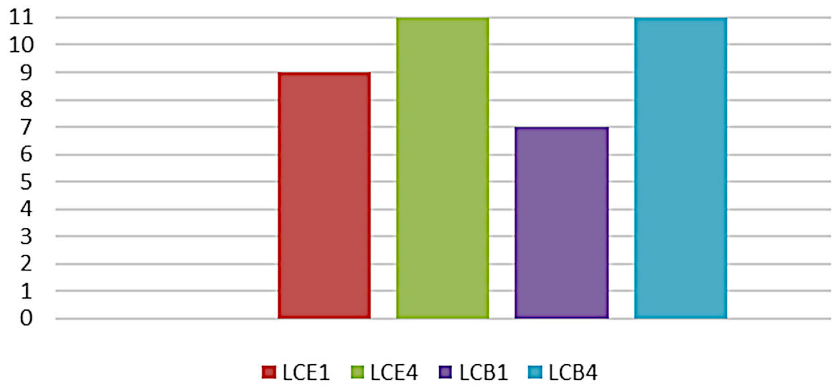
Table 1 – Coding and identification of participants

Participants	Quantity of students	Codes
First-year students pursuing a degree with a teaching certificate in Biological Sciences	07	LCB1X
Last-year students pursuing a degree with a teaching certificate in Biological Sciences	12	LCB4X
First-year students pursuing a degree with a teaching certificate in Exact Sciences	08	LCE1X
Last-year students pursuing a degree with a teaching certificate in Exact Sciences	13	LCE4X

Source: prepared by the authors.

Participating in the survey were a total of 39 students earning a degree and teaching certificate. **Figure 1** depicts the main characteristics of the participants in this study.

Figure 1 – Participants' data



Source: prepared by the authors.

Results

In our analysis, we opted to utilize two distinct questions to more effectively elucidate the varying methodological approaches and ideas that aspiring teachers have concerning students' knowledge of the Earth's shape. Firstly, we will present the answers to the question *What do you think about this student's response?* and then we will present the answers to the question: *What teaching strategies would you recommend in this situation?*

Answers to the question: what do you think about this student's response?

The first category – *Common sense* or *sense-based* – encompasses any answer that hint that the student's response relied on common sense or on knowledge that is constructed by children through their senses. There are four members in this group, all of which are first-year students taking Exact Sciences. Following are some extracts from their answers:

LCE1-01 *Students, through sensory perception, have the impression of walking in a straight line when it comes to Earth.*

LCE1-03 *The student does not have the grasp of a spherical/geoidal Earth. Instead, they believe that the horizon sets the boundaries of the planet.*

LCE1-05 *It might be an intuitive interpretation based on an incomplete understanding of the Earth's sphericity...*

LCB1a2 *A commonsense response!*

As we discussed in the theoretical framework presented earlier, the notion of a round Earth is one that children must build. That is, as reported by the researched students, it originates primarily from their *senses*. This initial understanding can be quite interesting if we later develop this *everyday* concept. Afterwards, we will elucidate the pedagogical and methodological strategies that the prospective educators suggested for instructing about the shape of the Earth.

LCE1-08 Totally out of touch with reality.
LCE1-02 I find it a very simplistic answer.
LCE4-07 It is wrong because the Earth is not flat.
LCB1a6 Mistaken.
LCB4a8 The student's answer is wrong, according to scientific consensus.

Due to the constraints of an online form, we were unable to provide the respondent with additional context or alternative suggestions, but we can still infer that most undergraduates in this case are graduating without giving much thought to the question of what constitutes an error. Hence, we conclude that prospect teachers can end up replicating educational practices that fail to consider student's thought process and the significance of errors in the learning process (BARTELMEBS, 2016; BARTELMEBS; HARRES, 2017).

In the third category – *Conspiracy Theory* – are the answers that mention the Flat Earth theory. Even though the hypothetical situation did not mention it, several prospective educators detected elements of this conspiracy theory in the student's response. This category received nine responses. Six undergraduates are from Exact Science programs, with half being first-year students and half being final-year students. The remaining three students are from the final year of the Biological Sciences program. Some excerpts are as follows:

LCE1-09 [...] *the student's answer is that of a flat-earther*.

LCE4-03 *The student responded in an unscientific manner. The student could be a flat-earther*.

LCE4-05 *I think this student got caught up in the Flat Earth theory*.

LCE4-06 *The student seems to think the Earth is either flat* [...]

LCB4a2 *Based on scientific knowledge, the response is wrong, but it reflects the student's familiarity with the topic and on a growing popular belief*.

LCB4a10 *This student is receiving information from the Flat Earth Theory nutcases*.

LCB4a1 *Wrong, because that sounds like the Flat Earth concept*.

The Flat Earth theory has been receiving increased attention in the media, particularly on social media platforms. However, it is not a novel concept, as we have illustrated in our theoretical framework based on Silveira (2017).

Responses falling under the fourth category – *Construction of scientific knowledge* – consider the fact that students are developing their scientific knowledge and that doing so may cause them to make some mistakes in the process. In this category, we received a total of seven responses. Four of these responses were from final-year Exact Sciences students, while the remaining three were from Biological Sciences students, of which only one was a final-year student.

LCB1a5 *This is the student's truth, so it's not totally wrong, for so, as the teacher, I would teach the correct shape according to science*.

LCB1a7 *Acceptable*.

LCE4-12 *It depends on the student's school grade… if the student is in the 6th grade [where, apparently, they introduced to celestial objects and their characteristics], I will find it normal, is not uncommon for them to perceive the planet as flat due to their limited perspective. But if a student continues to hold this belief, it would be a cause for concern. In such a case, I would try to show why the Earth is spherical*.

LCE4-10 *I think it's normal for some students in the early years of elementary school to have this idea about the shape of the Earth*.

LCE4-04 *A valid response, given that the student thinks this is a possibility in that situation*.

It is understood that the preceding answers convey an initial stance regarding the student's response within a hypothetical scenario that allows for greater adaptability. It is worth noting that the tendency to relativize errors is more prevalent among Exact Sciences students in their final year of study. In the field of Biological Sciences, however, most first-year students agreed with this perspective.

The final category was developed to draw attention to three participants' responses that point to a problem with science teaching and may have their roots in a dogmatic interpretation of religious doctrine. We named this category *Religious knowledge*. Three first-year Biological Sciences students used their answers to explain what the Holy Scriptures reveal about the shape of the Earth.

> LCB1a3 *It appears that the individual in question holds the belief that the Earth is not spherical, but rather flat. They also suggest that walking to the edge of the Earth would result in falling into the void, which is not accurate even according to the Flat Earth theory. This theory posits that the Earth is surrounded by a circle of glaciers that encircle the oceans in 360-degree fashion, and beyond that lies the Dome, as it is written in the Holy Bible*.

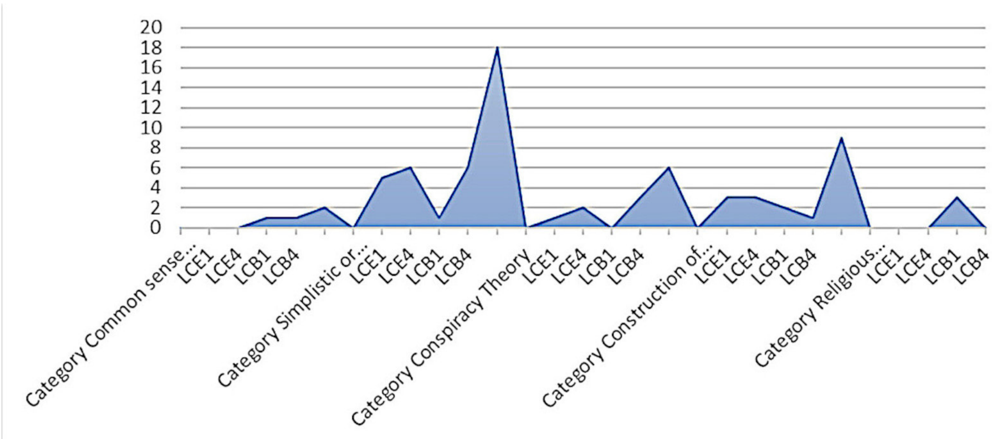
> LCB1a4 *The firmament, geomagnetic field, supports a dome on columns, like a molten mirror, on the Earth* [Job 26.7 Job 37.18], *being impossible to fall in an empty space. The student is completely wrong*.

> LCB1a1 *He is very wrong! How crazy! There is no way to fall into nothingness* [Job 26:7], *for the firmament – geomagnetic field – supports on columns a dome of molten mirror over the face of the Earth* [Gen 1:6; Ps 75:3; Is. 40:22; Job 37:18].

This situation may lead us to think about how perilous is the overlapping of dogmatism above schools and secular teaching, even if it is a right protected by the Brazilian Constitution. Furthermore, it is important that future teachers discuss this topic (RICETO; COLOMBO JUNIOR, 2019) and realize that the religious and scientific views occupy different epistemological spaces in both teachers' and students' lives.

We present in **figure 2** a summary of all the categories constructed for the analysis of the answers to the first question.

Figure 2 – Summary of the analysis result for the first question



Source: prepared by the authors.

Answers to the question: which teaching strategies would you propose for this situation?

In this inquiry, we are guided by the premise of Harres's (2001) work to categorize the answers of our research participants. The author proposes overcoming the: "[...] dilemma between radically empiricist or radically apriorist epistemological positions"

(HARRES, 2002, p. 283, our translation). However, in our study, it was not attainable to assess the responses in a broader context. Therefore, we restricted ourselves to categorizing the theoretical methodological preferences of prospective educators and aligning them with pedagogical concepts that are more closely associated with constructivism or an empiricist perspective on science education (BECKER, 2001).

Becker (2001) provides three ways of representing the school teaching and learning process. The first is based on directive pedagogy. Empiricism is the foundation of this view on knowledge. The teacher imparts knowledge to the students. Transmission is the sole method of learning in this approach. The subsequent method is based on non-directive pedagogy. Apriorism serves as its epistemic foundation. In this paradigm, teachers do not intervene with the learning process. This is determined by heredity. Students learn for themselves, being labeled a deficit in the event that they do not learn. The third kind of representation focuses on the concept of relational pedagogy. Its epistemological basis is the bond between the subject and the object. Heredity does not determine ability to learn. It is given by action and meaning. There is mutual learning and teaching between pupils and educators. In our analysis, we used empiricist and constructivist conceptions, leaving aside the a priori conception.

In the category of *Approach via concrete activities*, the information provided by the future teachers is consistent with an empiricist worldview of learning. It is worth mentioning that most individuals in this group are prospective educators who are currently completing their teacher training program. While not strictly following a constructivist model, the focus remains on the student's agency in their approach. In these cases, we understand that these future teachers advocate for concrete activities as they recognize that their significance in comprehending the shape of our planet.

As the excerpts below illustrate, recommendations showing the use of photographs, satellite images of the Earth, and other forms of audiovisual material were particularly common in this initial group.

> LCE4-02 *I would show images of astronomical observatories and facts that prove the truth* [...].
>
> LCE4-10 *Through images and scientific evidence, I would show the real shape of the Earth, in addition to explaining why the horizon seems straight*.
>
> LCB4a6 [I] *would seek to show them photographs of the Earth captured during the Apollo 11 mission.*
>
> LCB4a8 *I believe that showcasing documentaries that confirm the Earth's shape or demystify that the Earth is flat could prove advantageous*.

The use of visual aids to illustrate astronomical concepts is crucial in enhancing comprehension, particularly since these ideas entail a certain level of abstraction (BARTELMEBS, 2016). The undergraduates have suggested additional resources to incorporate the theme of education, including the utilization of teaching models and observational experiments through demonstrations, as indicated in their responses:

> LCE4-06 *I would display a few flight routes along with their lengths on a globe and a world map. Even if a student imagines the Earth to be flat, when routes are projected across the globe, the shortest one between any two spots on the earth may not be the one depicted as a straight line on the map.*
>
> LCB4a3 [...] *if it is possible to use an experiment like the Alexandria Well to show the curvature of the Earth.*
>
> LCB4a9 *For example, presenting teaching models about the phases of the moon and the seasons of the year. Such strategies would be indirectly responsible for demonstrating Earth's sphericity*.

In the second category, named *Proposal for Theoretical Exposition of the Theme*, we grouped the answers that suggested historical or theoretical approaches without specifying whether they utilized visual aids or practical activities to support their explanation. The activities designed by these future teachers are not solely grounded on an empirical foundation. While there are elements of constructivist pedagogy present, the focus of the activity remains centered on the teacher. For instance, consider the undergraduates' responses below.

> LCE1-05 *Pointing out diverse historical views is helpful*.
>
> LCE1-07 *First, I would explain the theories and facts, then move on to the difference between the round and flat Earth*.
>
> LCB4a3 *I would inquire as to why the student believes that the Earth is flat and then attempt to demonstrate, through argumentation, why the Earth is similar to a sphere*.

Matthews (1995) argues that recognizing how scientific knowledge has evolved over time is helpful in identifying and addressing erroneous assumptions about science. In this case, it may prove to be an effective pedagogical approach to challenge the erroneous notion that scientific knowledge is static, conclusive, and absolute, or that it requires minimal justification.

Moreover, a participant (LCB1a4) suggested employing religious premises as a teaching strategy for understanding the shape of the Earth: "[…] *to read the word of God, the creator of heaven and earth, for his understanding no one can fathom* [Isaiah 40:28]… *but human knowledge is limited – there're scriptures*". When looking at basic education, it is a frequent occurrence for debates and discrepancies to arise between science and religion, resulting in a multitude of uncertainties and clashes. As previously stated, it is imperative to recognize that religious and scientific perspectives exist within distinct epistemological domains (RICETO; COLOMBO JUNIOR, 2019).

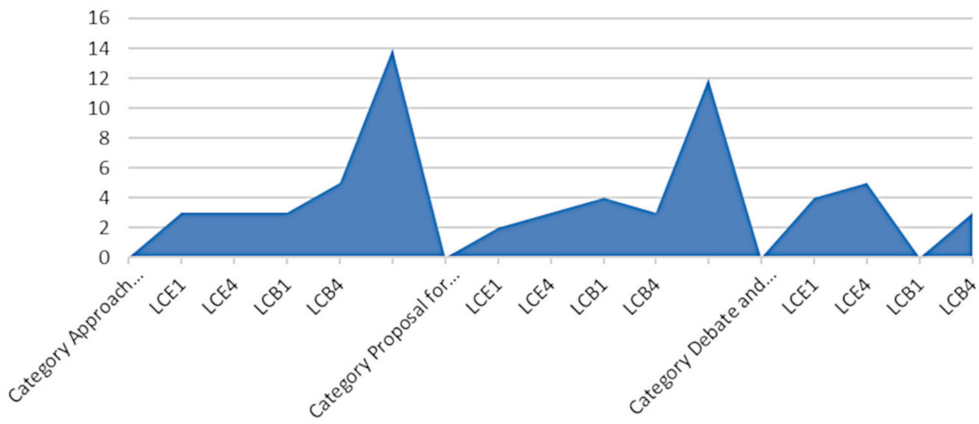
Finally, our last category – *Debate and research proposal* – shows the answers related to collaborative strategies in the classroom, which can be an unrestricted activity, similar to an informative conversation, as reported by the LCE1-05 undergraduate: "*I would ask questions to encourage the student to rethink their misunderstandings*". In this category, we can see signs of a constructivist pedagogical approach in the activities proposed by the future teachers. An An alternative option could be more complex activities that involve research and student presentations:

> LCE4-11 *I would consider implementing a strategy that one of my former teachers used. This strategy involves dividing the class into two groups and have each group present their arguments on whether the Earth has a specific shape. After each group present their theories, having achieved or not the objective, I would first show a video that provides evidence of the Earth's shape. If any doubts or questions arise, I would try to solve them right away or in following class*.
>
> LCE4-06 *I recommend organizing a debate activity for the students to conduct research and engage in a discussion, ultimately leading to the development of the understanding that the earth is not flat*.
>
> LCB4-a9 *As a teacher concerned with the scientific literacy of my students, I would recommend incorporating additional astronomy concepts into our curriculum. For instance, we could explore how to tell the time using a Gnomon, study the phases of the moon, and examine the different seasons of the year. These strategies would be presented using didactic models and could potentially contribute to indirectly illustrating the spherical shape of planet Earth*.

Many researchers have already demonstrated the importance of debate in the classroom. According to Rodrigues, Pereira, and Sabka (2017), debate not only offer social advantages, but they also serve as a powerful tool to prompt students to engage in selfreflection from their own perspective. Additionally, the critical thinking skills fostered by classroom discussions have been shown to have a positive impact on student's self-confidence and even academic achievement.

We present in **figure 3** a summary of all the categories constructed for the analysis of the answers to the second question.

Figure 3 – Summary of the analysis result for the second question



Source: prepared by the authors.

Final remarks

Upon revisiting our study question (*What are the didactic-methodological conceptions of future teachers about the shape of Earth?*) and analyzing the findings – also based on the first question to which the participants responded (*What do you think of this student's answer?*) – we can observe that most future teachers take the student's previous knowledge about the shape of the Earth into account. However, most of the answers consider the student's response as a mistake, a simplistic view, or even one that is linked to a conspiracy theory.

The majority (five) of those in the first group consider that the student's response is incorrect. However, three of the nine responders already show signs of a vision that recognizes the importance of students' views and their need to be acknowledged in the classroom. Only one participant referred to this as a possible response to flat-earth and other denialist theories.

Future teachers of Biological Sciences who are commencing their course made the greatest number of answers associated with personal religious beliefs. Out of the seven subjects within this category (LCB1), three have defined the student's thought process through biblical citations, recommending interpretation of biblical passages to address these uncertainties. Other two have put forth the perspective that the ideas presented by the student are a part of the process of learning, while only one identified it as an error.

When examining first-year students versus those who are nearing graduation, it becomes apparent that the notion that a student's answer is incorrect persists. Out of the eleven future teachers in the LCE4 group, six contend that the response provided by the student is erroneous, yet they do not engage in any discussion or contextualization of said error. Only three future teachers have mentioned the potential of utilizing this student's concept as a foundation for constructing a novel and correct understanding of the Earth's shape. Nonetheless, in two undergraduates' answers, the student's response is founded on flat-Earth denialist thinking. Amongst the group of upcoming Biological

Sciences teachers who are nearing the completion of their program (LCB4), six of the 11 respondents maintain the perspective that the student's response is incorrect and have not presented any substantiating proof to support a viewpoint that would contextualize this mistake. One future educator believes that the answer is grounded in common sense, while three others believe that this student may be adept at denialist theories.

In response to our second question, on the teaching strategies recommended, except for the exact sciences course, where there appears to be more evidence of the creation of constructivist pedagogy, we saw an obvious shift in methodological responses between first-year and final-year groups in all courses. Besides, those enrolled in Biological Sciences programs continue to place a premium on teacher-led expositions and activities, while those studying Exact Sciences recommend research-based activities and discussions in the classroom, thereby engaging students more deeply in their educational pursuits.

The future teachers of the LCE1 group, who are at the beginning of their training, hold methodological views that are closer to a constructivist perspective. Four out of the nine subjects investigated indicated that they would utilize research activities and classroom discussions to challenge student responses. Three prospective educators align with the empiricist pedagogical approach, in the sense that it advocates for hands-on activities as the primary method of instructing students on the Earth's shape. The remaining two argue that a good theoretical exposition could solve the problem. Concerning the group of juniors in Biological Sciences (LCB1), four out of seven participants emphasize the significance of carrying out a good theoretical exposition. Two of these suggest using the Bible. Finally, three participants defend the use of tangible objects to facilitate students' comprehension of the Earth's shape, yet discussions or investigations are not pushed forward.

We noticed a difference between the LCE1 and LCB1 groups because, even if timidly, constructivist notions as a methodological approach in educational practice are already present among the students of the LCE1 group, whereas there was no manifestation in this way in LCB1. Perhaps there is a curricular factor in it since the LCE's program includes courses on Pedagogy and Didactics from its beginning, but LCB students will only come into touch with fields other than that of Biological Sciences starting in their third year.

We observed a distinct progression in the LCE4 group's perceptions in comparison with their peers at the first academic term. Five of the eleven participants support the use of scientific research in classrooms as a good strategy to addressing the topic of Earth's shape. Other three support the use of a theoretical exposition, which, depending on how it is implemented, has the potential to function as a constructivist pedagogical tool. However, as we cannot infer anything beyond what the students answered us, we categorized the data separately according to the activities in which they explicitly used terms such as research and debate. Finally, from this group, three defended the use of tangible resources such as visuals, cartography, or virtual models. But they did not clarify whether these objects would only be shown to the students or if they would be part of an interactive activity.

In the LCB4 group, however, the prevailing approaches were methodological in character and in line with what we classify as an empiricist view. Of the 11 future teachers, five stated that they would use physical objects to help their pupils better understand the Earth's shape. Again, we are limited to what students wrote in their answers. However, given that the students have not referenced any extracurricular or previous activities, we deduce that this recommendation serves as a preliminary measure in imparting information to the students. In comparison to the LCE4 group, we have observed that students in the LCB4 group still demonstrates a lack of comprehension and execution in terms of constructivist classroom methodologies. Three future teachers defend the integration of debates and research in the classroom, while three others define their strategies as in a teacher-centered theoretical exposition. It is understandable, given that the Biological Sciences undergraduate degree program of the university where we conducted our research still requires to move away from an outmoded approach to instructor preparation that prioritizes expository and theoretical courses in Biological Sciences over pedagogy and teacher training.

Ultimately, it has come to our attention that there appears to be a discrepancy when contrasting the answers to the initial question with those provided for the second one. This is because when prospective educators responded to our inquiry regarding their perception of the student's response, there seemed to be a greater emphasis on constructivist principles in their viewpoints. The majority of the undergraduates' responses conveyed an understanding of the presence of alternative conceptions and the fact that they are not inherently negative. However, the predominance of a constructivist pedagogical and methodological approach is not as significant when they were asked about the teaching strategies that they would utilize in the classroom. We understand that this may stem from a potential alteration in methodological terms (but not at an epistemological level) of the future educators' own conceptions throughout the duration of the program. To achieve the amount of change envisioned in Harres' (2002) essay, we still need to promote, in our undergraduate courses, the conceptual evolution of our future teachers, so that their learning concepts might gradually approach a constructivist perspective.

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References

ALBUQUERQUE, A; QUINAN, R. Crise epistemológica e teorias da conspiração: o discurso anti-ciência do canal "professor Terra plana". *Mídia e Cotidiano*, Niteroi, v. 13, n. 3, p. 83-104, 2010.

ANDRADE, P. E.; PRADO, P. S. Psicologia e neurociência cognitivas: alguns avanços recentes e implicações para a educação. *Interação em Psicologia*, Curitiba, v. 7 n. 2, p. 73-80, 2003. Doi: https://doi.org/10.5380/psi.v7i2.3225.

BAIG, A.; AGUSTENCH, M. *La revolución científica de los siglos XVI y XVII*. Madrid: Alhambra, 1987.

BARDIN, L. *Análise de conteúdo*. Lisboa: Edições 70, 2016.

BARTELMEBS, R. *O ensino de astronomia nos anos iniciais*: reflexões produzidas em uma comunidade de prática. 2012. Dissertação (Mestrado em Educação em Ciências) – Universidade Federal do Rio Grande, Rio Grande, 2012.

BARTELMEBS, R. C. *Ensino de astronomia nos anos iniciais do ensino fundamental*: como evoluem os conhecimentos dos professores a partir do estudo das ideias dos alunos em um curso de extensão baseado no modelo de investigação na escola. 2016. Tese (Doutorado em Educação em Ciências e Matemática) – Pontifícia Universidade Católica do Rio Grande do Sul, Porto Alegre. 2016.

BARTELMEBS, R. C.; HARRES, J. B. S. As ideias dos alunos, as ideias dos professores e a aprendizagem: uma revisão conceitual. *In*: MARRAGHELLO, G. F., LINDEMANN, R. H. (org.). *Ensino de ciências na região da campanha*: contribuições na formação acadêmico-profissional de professores em astronomia. Itajaí: Casa Aberta Editora, 2017. p. 11-52.

BATISTA, M. C. A formação de professores dos anos iniciais para o ensino de astronomia no estado do paraná. *Ensino & Pesquisa*, União da Vitória, PR, v. 14, n. 2, 2016. Disponível em: https://tinyurl.com/bddxkpnv. Acesso em: 22 out. 2021.

BECKER, F. *Educação e construção do conhecimento*. Porto Alegre: Artmed, 2001.

BEZERRA, R. A terra plana é aqui. *Revista X*, Curitiba, v. 15, n. 4, p. 21-29, 2020.

BOGDAN, R. C.; BIKLEN, S. K. *Investigação qualitativa em educação*: uma introdução à teoria e aos métodos. Porto: Porto Editora, 1994.

BRETONES, P. S. *Disciplinas introdutórias de astronomia nos cursos superiores do Brasil*. 1999. Dissertação (Mestrado em Geociências) – Instituto de Geociências, Universidade Estadual de Campinas, Campinas, 1999.

CASATI, R. *A descoberta da sombra*: de Platão a Galileu, a história de um enigma que fascina a humanidade. São Paulo: Companhia das Letras, 2001.

CHALMERS, A. F. *O que é ciência afinal?* São Paulo: Brasiliense, 1993.

HARRES, J. B. S. A evolução do conhecimento profissional de professores: o caso do conhecimento prévio sobre a forma da terra. *Caderno Catarinense de Ensino de Física*, Florianópolis, v. 18, n. 3, p. 278-297, dez. 2001.

IACHEL, G. *Os caminhos da formação de professores e da pesquisa em ensino de astronomia*. 2013. 201 f. Tese (Doutorado em Educação para a Ciência) – Faculdade de Ciências, Universidade Estadual Paulista, Bauru, 2013.

JIMÉNEZ-T.; L. OTERO, J. La educación científica frente al pensamiento anticrítico en la vida diaria. *Enseñanza de las Ciencias*, Barcelona, v. 37, n. 1, p. 117-135, 2019.

KUHN, T. *A revolução copernicana*. Lisboa: Edições 70, 2002.

LANGHI, R. *Astronomia nos anos iniciais do ensino fundamental*: repensando a formação de professores. 2009. Tese (Doutorado em Educação para a Ciência) – Faculdade de Ciências, Universidade Estadual Paulista, Bauru, 2009.

LANGHI R.; NARDI, R. Dificuldades interpretadas nos discursos de professores dos anos iniciais do ensino fundamental em relação ao ensino da astronomia. *Revista Latino-Americana de Educação em Astronomia*, São Carlos, n. 2, p. 75-92, 2005. Doi: https://doi.org/10.37156/RELEA/2005.02.075.

LANGHI, R.; NARDI, R. Trajetórias formativas docentes: buscando aproximações na bibliografia sobre formação de professores. *Alexandria*, Florianópolis, v. 4, p. 7-28, 2012.

LEITE, C. *Os professores de ciências e suas formas de pensar a astronomia*. 2002. Dissertação (Mestrado em Ensino de Ciências) – Universidade de São Paulo, São Paulo, 2002.

LEITE, C.; HOSOUME, Y. Os professores de ciências e suas formas de pensar a astronomia. *Revista Latino-Americana de Educação em Astronomia*, São Carlos, n. 4, p. 47-68, 2007.
Doi: https://doi.org/j6r6.

MATTHEWS, M. História, filosofia e ensino de ciências: a tendência atual de reaproximação. *Caderno Brasileiro de Ensino de Física*, São Paulo, v. 12, n. 3, p. 164-214, 1995.

OLIVEIRA, L. A construção do espaço, segundo Jean Piaget. *Sociedade & Natureza*, Uberlância, v. 17, n. 33, p. 105-117, 2005. Doi: https://doi.org/j6r7.

OLIVEIRA, L. B. Teorias conspiratórias na era digital: reflexões sobre o papel da geografia escolar frente a desmistificação da teoria da terra plana. *Revista Tamoios*, São Gonçalo, v. 17, n. 1, p. 49-64, 2021. Doi: https://doi.org/j6r8.

PEREIRA, A. M.; VILAÇA, J.; RODRIGUES, S. formação de educadores em ensino de astronomia. *In*: ENCONTRO NACIONAL DE PESQUISA EM EDUCAÇÃO EM CIÊNCIAS, 9., 2013, Águas de Lindoia. *Atas* [...]. São Paulo: ABRAPEC, 2013.

PIAGET, J.; GARCÍA, R. *Psicogênese e história das ciências*. Petrópolis: Vozes, 2011.

PIAGET, J.; INHELDER, B. *A representação do espaço na criança*. Porto Alegre: Artes Médicas, 1993.

PIAGET, J. *Introduction à l'epistemologia génetique v. 1*: la pensée matematique. Paris: PUF, 1949.

PILATI, R. *Ciência e pseudociência*: por que acreditamos naquilo em que queremos acreditar. São Paulo: Contexto, 2020.

PIVARO, G. F. A crença numa terra plana e os ambientes virtuais: identificando relações e construções de conhecimento. *In*: ENCONTRO NACIONAL DE PESQUISA EM EDUCAÇÃO EM CIÊNCIAS, 12., 2019, Natal. *Anais* [...]. Natal: Universidade Federal do Rio Grande do Norte, 2019. p. 1-7.

PRADO, A. F. *O que há neste diário?*: a mobilização de saberes docentes durante um curso de astronomia para professores dos anos iniciais do ensino fundamental. 2019. Dissertação (Mestrado em Educação para a Ciência) – Faculdade de Ciências, Universidade Estadual Paulista, Bauru, 2019.

RICETO, B.; COLOMBO JUNIOR, P. Diálogos entre ciência e religião: a temática sob a ótica de futuros professores. *Revista Brasileira de Estudos Pedagógicos*, Brasília, v. 100, n. 254, p. 169-190, 2019. Doi: https://doi.org/j6r9.

RODRIGUES, R. F.; PEREIRA, A. P.; SABKA, D. R. O debate entre argumentação e explicação: uma análise no contexto de seminários de astronomia. *Enseñanza de las Ciencias*, Barcelona, n. extra, p. 4571-4574, 2017.

SILVA, J. A.; MARINHO, J. C. B.; SILVA, G. R.; BARTELMEBS, R. C; SILVEIRA, J. B. Sensação e percepção no contexto dos estudos em epistemologia genética. *Schème*: revista eletrônica de psicologia e epistemologia genéticas, Marília, v. 6, n. 2, p. 51-67, 2014. Disponível em: https://revistas.marilia.unesp.br/index.php/scheme/article/view/4652. Acesso em: 20 abr. 2023.

SILVA, S. R.; LANGHI, R. Formação de professores para o ensino de astronomia: efeitos de sentido sobre a prática. *Alexandria*, Florianópolis, v. 14, n. 2, p. 209-224, 2021.

SILVEIRA, F. L. Sobre a forma da terra. *Física na Escola*, São Paulo, v. 15, n. 2, p. 1-11, 2017. Disponível em: https://tinyurl.com/r7xxpyhu. Acesso em: 20 dez. 2021.