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Scientific distortions assessed in non-formal learning environments and their effects on conceptions about Astronomy and Astronautics in Brazilian Northeastern

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Abstract. The project Caravana Luar do Sertão, supported by CNPq, investigated scientific literacy and misconceptions about Astronomy and Astronautics in non-formal learning environments, with an inclusive approach. Over two years, more than 450 people from 50 cities in six Northeastern states were interviewed about beliefs in science, pseudoscience, Moon missions, celestial phenomena, and astronautics. Results revealed widespread misconceptions: 20% consider both Astronomy and Astrology sciences, 10% doubt the Lunar mission, one-third believe the Sun orbits the Earth, and only one-third correctly understand Moon phases. Older people, specially women, were rarely recognized as potential astronauts, however the Brazilian astronaut is still recognized even after 20 years of his last spatial mission. Half of participants assumed astronomical images are identical to telescope views. The study highlights the scarcity of similar research in Brazil with comparable scope and depth.

Resumo. O projeto Caravana Luar do Sertão, financiado pelo CNPq, investigou a alfabetização científica e os equívocos sobre Astronomia e Astronáutica em ambientes de aprendizagem não formal, com uma abordagem inclusiva. Ao longo de dois anos, mais de 450 pessoas de 50 cidades em seis estados do Nordeste foram entrevistadas sobre crenças em ciência, pseudociência, missões lunares, fenômenos celestes e astronáutica. Os resultados revelaram equívocos generalizados: 20% consideram tanto a Astronomia quanto a Astrologia como ciências, 10% duvidam da missão lunar, um terço acredita que o Sol orbita a Terra e apenas um terço compreende corretamente as fases da Lua. Pessoas mais velhas, especialmente mulheres, raramente foram reconhecidas como potenciais astronautas; no entanto, o astronauta brasileiro ainda é reconhecido mesmo após 20 anos de sua última missão espacial. Metade dos participantes supôs que as imagens astronômicas são idênticas às vistas pelo telescópio. O estudo destaca a escassez de pesquisas semelhantes no Brasil com escopo e profundidade comparáveis.

Keywords. Teaching of Astronomy – Sociology of Astronomy

1. Introduction

Astronomy and space exploration have long occupied a central role in scientific, technological, and social development, while simultaneously permeating the popular imagination. This dual presence has made the field especially susceptible to the spread of misinformation and speculative narratives, such as the confusion between Astronomy and Astrology, predictions of imminent cosmic catastrophes, and conspiracy theories including flat Earth, neogeocentrism, and the denial of the Moon landing Allcott & Gentzkow (2017); Goertzel (1994); Korta (2018); Vermeule & Sunstein (2009). The rise of digital media has intensified these phenomena, enabling rapid dissemination of "fake news" and conspiratorial interpretations of scientific topics, often decoupled from mechanisms of verification and critical evaluation Vermeule & Sunstein (2009); McIntyre (2015).

Such challenges highlight the importance of scientific literacy initiatives and public engagement strategies capable of fostering critical understanding and informed decision-making Cunha (2017); Mamede & Zimmermann (2005); Motta-Roth (2011); Sasseron & Carvalho (2011). In this context, large-scale scientific programs, such as the Artemis Mission Smith et al. (2020), gain renewed relevance by providing concrete opportunities to refute pseudoscientific claims, promote inclusive scientific imagery, and strengthen public trust in Science. Based on these discussions and taking advantage of this opportunity, we proposed and had approved the project CNPq/MCTI/FNDCT n^o 408662/2022-0 (Scarano Jr. et al. (2022)), which, among other initiatives for the dissemination of Astronomy and Astronautics, carried out a study involving the general public across a broad region covered by the project to examine public conceptions related to Astronomy and Astronautics in Northeastern Brazil using the method of dialogic interview. This investigation explored not only conceptual understanding but also beliefs, misconceptions, and sociocultural perceptions surrounding Space Sciences.

2. Methods

The questions asked in the interview can be categorized into central groups (according the subsection in section 3) to facilitate the reference. They were written in a way that maintains consistent themes throughout the interview, even when the questions address different topics. Initially, only the complete form with ten questions was available. However, to make data collection more efficient and to obtain the largest possible number of responses, the instrument was later divided into two versions based on the availability of the interviewee is directed to a simplified form with only two questions.

At the beginning of each interview, the researcher categorized the respondent according to two variables: perceived gender ("m" for male and "f" for female) and age group ("c" for children, "j" for youth, "a" for adults, and "i" for the elderly). In addition, space was provided for the interviewer to record notes when necessary, allowing the registration of subjective perceptions that would otherwise be excluded by the structured format.

To favor active listening and the perception of subjective expressions, the form was applied dialogically, with the questions

verbalized and the language adjusted to ensure optimal comprehension by the interviewee. The integrity of the original questions was preserved, while the dialogical approach enabled the interviewer to better identify which answer option most accurately represented the participant's belief.

Because the process continuously adapted to the public's needs, interviews lasted between 3 and 11 minutes, with a median of 8 minutes, corresponding to approximately one minute per question. All ten questions and their respective answer options were as follows:

Q1: Which of these words are associated with sciences? [*Cosmology; Astronautics; Astrophysics; Astrology; Astronomy; Ufology.*]
Q2: Which of these objects orbits the Earth? [*Sun; Moon; Planets; Comets; Satellites.*]
Q3: What happens to the stars during the day? [*The light that comes from them dims with the Sun's presence; They disappear with the Sun's presence; They stop reflecting the Sun's light; Their shine gets mixed with the one from the bright sky; They are occult behind the horizon.*]
Q4: Do you believe that the humanity has already been to space or landed on the Moon? [*Never went to space nor to the Moon; Went to space, but not to the Moon; Went to space and to the Moon; Did all that and much more than what is disclosed; Did much less than that, manipulating what is disclosed.*]
Q5: During the Moon phases we see parts of it dark. Why does it happen? [*Because they are different Moons (we have 4 Moons); Because of the shadow of the Earth; Because it changes size; Because of the shadow of the Moon itself; Because of the shadow of the Sun itself.*]
Q6: About the Sun, it is correct to affirm: [*That it is a fireball; That it orbits the Earth; One day it will "go out"; It is a star; It is located at the same distance as the Moon in relation to us.*]
Q7: What is the Earth's approximate shape? [*Flat as a table; Spherical like a ball; Does not have a shape, because we cannot see it from outside; Infinite, because it has no limits.*]
Q8: The images we see from space are: [*Real, exactly like the ones we would see with our eyes through telescopes; Real, but manipulated as in montages; Real, but processed to accentuate certain information in the image; False, computer-generated.*]
Q9: Which of the following objects have a spherical shape? [*Planets; The Moon; Comets; Asteroids; The Sun.*]
Q10: Which of these people would you identify as astronauts? [*Followed by a sequence of 17 pictures of real astronauts, varying in age, gender, and ethnicity.*]

Note: The simplified form included only Q5 and Q10.

3. Results and discussion

3.1. Reached Audience

In total, 451 responses were collected over the course of 2 years, across 50 cities in 6 Northeastern states. The complete form was applied 397 times, while the simplified version yielded 54 responses. The answers were fairly distributed between perceived genders, with 51% of male responses and 44% of female responses (top of Fig. 1). The age-group distribution is presented at bottom of Fig. 1, indicating that the most recurrent participants were the young (35%) and adults (31%), followed by children (21%) and elderly individuals (2%). Undefined cases occurred in both gender (5%) and age (11%), which can be attributed to a technical error in filling the corresponding fields.

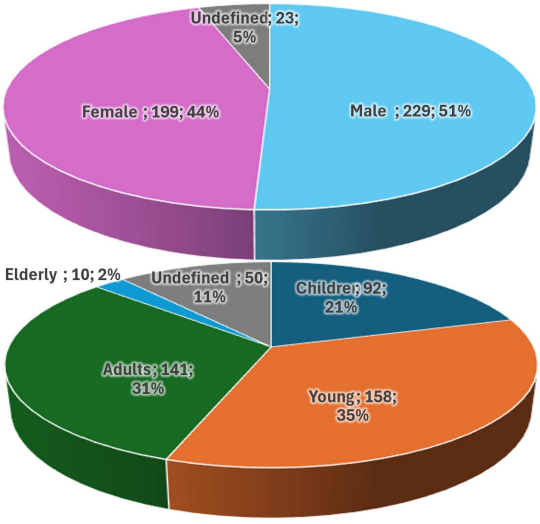

Figure 1. Gender and Age distribution selected by the interviewer.

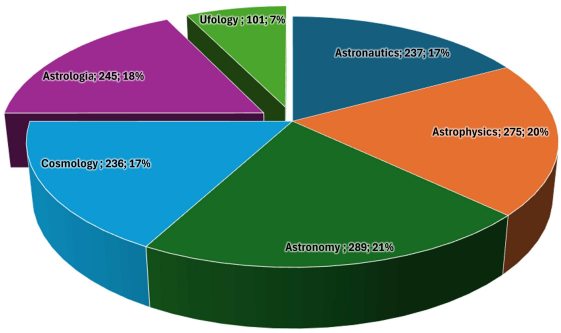

Figure 2. Accounting of the number of people who understand each of the terms presented as a science.

3.2. Contrast between Science and Pseudoscience

Although all questions contrast Science, Pseudosciences, and misconceptions, Q1 is the only one that explicitly explores this perception. The question used a multiple-selection format, allowing interviewees to choose more than one option.

The number of selections for each term is shown in Fig. 2, where the two detached slices correspond to pseudosciences. It is observed that the terms "Astronomy" and "Astrophysics" were identified as sciences in similar proportions, despite "Astronomy" being a more familiar word to the public.

One of the initial hypotheses was that the suffix "logy" would induce respondents to associate a term with scientific knowledge. However, "Cosmology" appeared with the same frequency as "Astronautics", a science, and "Astrology", a pseudoscience. The term "Ufology", despite sharing the same suffix, was the least frequently identified as a Science.

3.3. Questioning the Neogeocentrism

The belief in neogeocentric concepts can be evaluated mainly through Q2 and also Q6 that serves as a consistency indicator. As shown in Fig. 3, the only two correct answers (Moon and Satellites) were selected by approximately 2/3 of the participants. Meanwhile, the belief that the Sun orbits the Earth appeared consistently in around 30% of the public: 130 selections in Q2

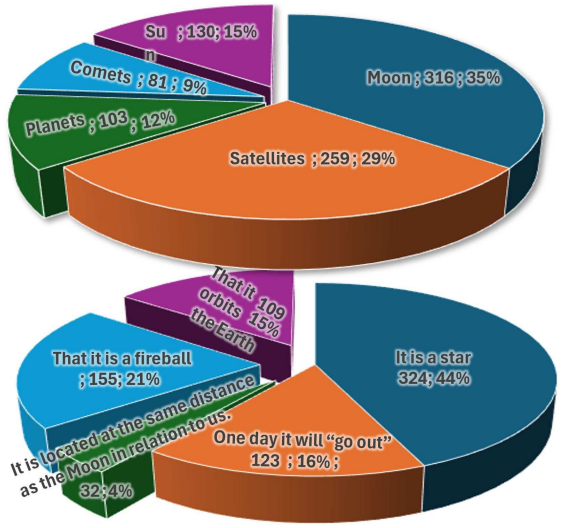

Figure 3. Top: Q2 Accounting of the number of people who identified which objects orbit the Earth. Bottom: Q6 Accounting of the number of people who identified each of the affirmations about the Sun as true

and 109 in Q6, out of the 397 participants who answered the complete form.

3.4. Physical Phenomena and Celestial Perceptions

This section encompasses topics related to physical phenomena and celestial perceptions that are frequently associated with mistaken conceptions. These themes were addressed in four questions: Q3, Q5, Q6, and Q8. Overall, most answers to these questions were incorrect.

For Q3, although the scientifically correct answer was chosen 40% of the time (one of the highest correct rates in the questionnaire) the mistaken answers still accounted for 60%, as shown in Fig. 4L. Among the incorrect responses, the most frequent (31%) was the belief that the stars' brightness dims due to the presence of the Sun. Although this perception may describe the visible effect, it assumes a dependence of a star's brightness on the Sun, a misconception also reflected in answers such as "they disappear with the Sun's presence" (14%) and "they stop reflecting the Sun's light" (9%). The least selected mistaken alternative was the only one that did not associate stellar brightness with the Sun: the idea that the stars are "hiding" behind the horizon (6%).

The cause of the Moon phases was evaluated through Q5, one of the two questions that compose the simplified form; therefore, all 451 participants answered it. As shown in Fig. 4M, 80% of the interviewees demonstrated mistaken conceptions.

A study conducted by Iachel et al. (2008) analyzed spontaneous conceptions on this topic among 40 high school students in the Bauru region, finding that approximately 20% were able to explain it correctly. Additionally, Saraiva et al. (2011) carried out a study with undergraduate Physics students at the Federal University of Rio Grande do Sul. In Saraiva's study, the correct response rate was around 50%. Although objectively higher than the previous study, this percentage remains low for a topic so closely related to their field of study.

The misconceptions explored in both Saraiva's study and the present one may be rooted in linguistic and interpretative challenges. Because the Sun is the source of the Moon's illumination, associating the Moon phases with a "shadow of the Sun" is a false but common correlation. This explanation was chosen by 21% of respondents, similar to the correct response rate (20%). However, the most frequent answer (41%) was neither the correct explanation nor the false correlation; instead, participants attributed the Moon phases to a shadow of the Earth. This confusion may stem from the association of lunar eclipses (during which Earth does cast a shadow on the Moon) with the everyday phenomenon of the Moon phases.

As shown previously in Figure 3B, Q3 revealed that approximately 30% of respondents believe that the Sun orbits the Earth. In addition to this misconception, around 40% of participants mistakenly believe that the Sun is a "ball of fire."

The majority of the surveyed audience correctly identified the Sun as a star (81%). However, only 30% recognized that it will eventually "go out." The least selected option stated that the Sun is located at the same distance from Earth as the Moon (0.08%).

Together with Q3, Q8 presented one of the highest success rates: 43% of respondents affirmed that the images are indeed real but processed.

The belief that the images appear exactly as they would to the naked eye through a telescope is nearly as frequent as the correct answer (44%), as seen in Fig. 4. However, this response cannot be considered accurate, since the human eye perceives light on a logarithmic scale, and image processing reveals details that would otherwise not be visible.

Among the least selected options, only 9% believe that the images are manipulated, and an even smaller proportion consider them to be entirely computer-generated (4%). It is important to note that this research began in 2022, prior to the rise of generative artificial intelligence capable of creating images from scratch.

3.5. Questioning Conspiracy Theories

This research also evaluated conspiracy theories, such as Moon landing denial (Q4) and flat Earth beliefs (Q7). In addition, Q8 and Q9 served as consistency indicators.

In Q7, respondents were presented with five answer options, including the possibility that humanity has been to both space and the Moon, to space but not the Moon, as well as options involving beliefs in manipulation by withholding or exaggerating information.

The results shown in Fig. 5T indicate that 87% of participants consider the human race to have been to the Moon, combining both options that stated "has been to the Moon". The second most selected option affirms that humanity has accomplished much more than what is publicly disclosed.

This option was initially included to represent conspiratorial thinking, assuming that undisclosed information would necessarily be the result of intentional manipulation. However, during the interviews, conducted dialogically, an alternative interpretation emerged: many participants selected this option to express their understanding that scientific research takes time, and that articles and data are not released instantaneously.

In this context, the high frequency of this response may not reflect distrust in science. On the contrary, it may reveal a more nuanced understanding of the scientific method and the time required for scientific information to become publicly available.

This interpretation is corroborated by Q8, given that only 4% of interviewees believe that space images are manipulated, far less than the 25% suggested by Q7.

A similar study conducted by DataFolha in 2019 concluded that 1 in every 4 Brazilians believes the Moon landing was faked Folha de S.Paulo (2019b). Their finding of 25% contrasts with the 13% observed in our study. This discrepancy may stem from the

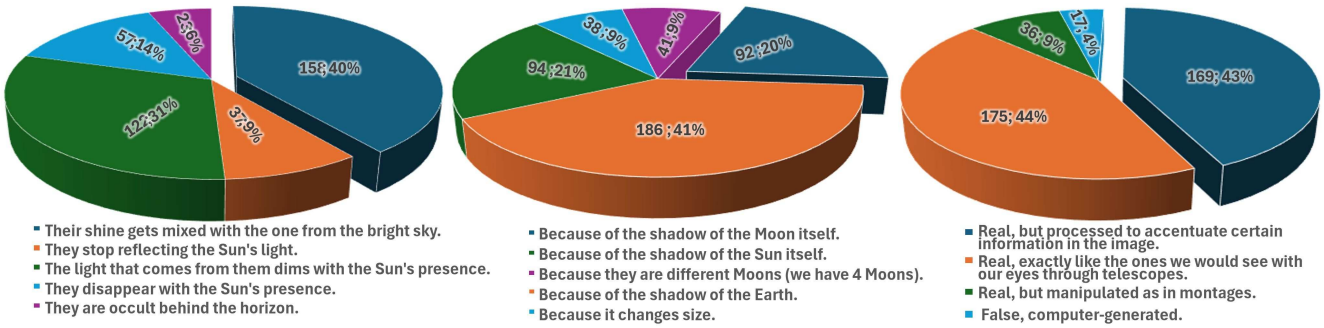

Figure 4. Left: Q3 Answer distribution for what happens to the stars during the day. Middle: Q5 Answer distribution for the cause of the Moon phases. Right: Q8 Answer distribution regarding the veracity of space images.

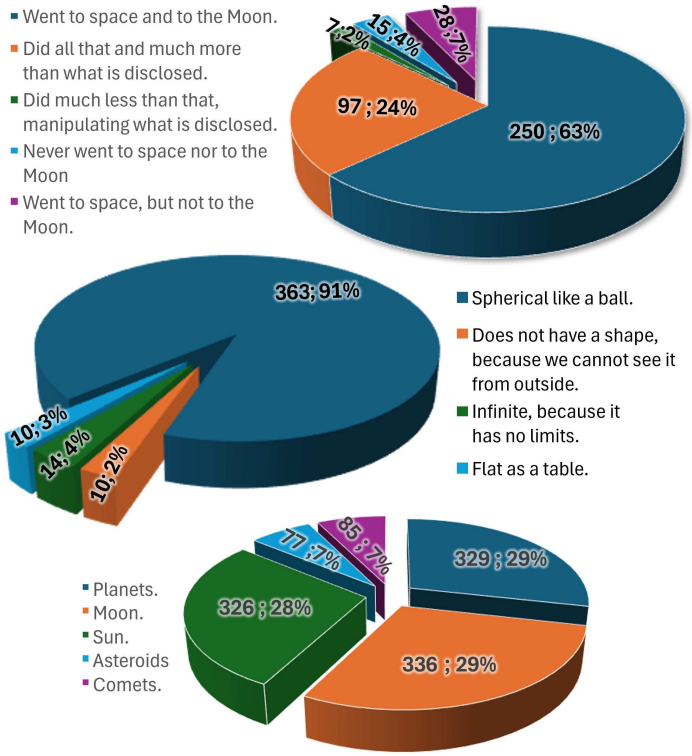

Figure 5. Top: Q4 Answer distribution for different beliefs regarding whether humanity has been to the Moon. Middle: Q7 Answer distribution for the shape of the Earth. Bottom: Q9 Answer distribution for different beliefs regarding whether humanity has been to the Moon.

dichotomous structure of DataFolha's answer choices, which may have limited the accurate representation of individual beliefs.

Another conspiracy theory addressed was the shape of the Earth (Q7). As shown in Fig. 5B, 91% of participants believe in an almost spherical Earth. Two articles published by DataFolha Datafolha (2024); Folha de S.Paulo (2019b) report similar results.

However, because our study subdivided "non-globalists" into three categories, we found a smaller percentage of "flat-earthers": only 3%, compared with DataFolha's 7%. Of the 10 participants who affirmed that the Earth is flat, 7 were children, a demographic not included in DataFolha's study.

3.6. Astronautics and Identity Issues

This study also offered a sociocultural perspective through Q10. In this final question, present in both the full and simplified forms, participants were shown 17 photographs of real astronauts and asked to select those they identified as such.

The purpose of this question was to evaluate potential biases related to age, gender, and ethnicity concerning who is perceived as capable of becoming an astronaut.

The most frequently selected, identified by 51% of participants, as seen in Fig. 6, was Marcos Pontes, the only Brazilian astronaut up to the moment . The second and third most selected individuals were Victor Glover and Christina Hammock, a Black man and a woman, both members of the Artemis II mission.

Our findings show no clear dependence on gender or ethnicity. However, a tendency for older female astronauts to be less frequently identified than younger ones was observed.

4. Conclusions

The results of this study provide a comprehensive overview of how different groups perceive fundamental astronomical concepts, revealing both persistent misconceptions and meaningful indications of scientific literacy.

While some topics, such as the causes of the Moon phases, the nature of the Sun, and the behavior of stars continue to show high rates of erroneous beliefs, other aspects demonstrate clearer understanding and consistency among participants. The analysis also indicates that, in some cases, responses initially interpreted as conspiratorial may instead reflect a more informed comprehension of scientific processes and the timescale required for knowledge production and dissemination. Furthermore, the sociocultural dimension explored through the identification of astronauts highlights the absence of strong gender or ethnic biases, although older women were identified as astronauts less frequently than younger women.

Overall, the study reinforces the importance of accessible science communication and educational strategies that address both conceptual misunderstandings and public perceptions of science. It also emphasizes the value of dialogical methodologies in revealing nuanced interpretations that would not emerge through traditional survey approaches.

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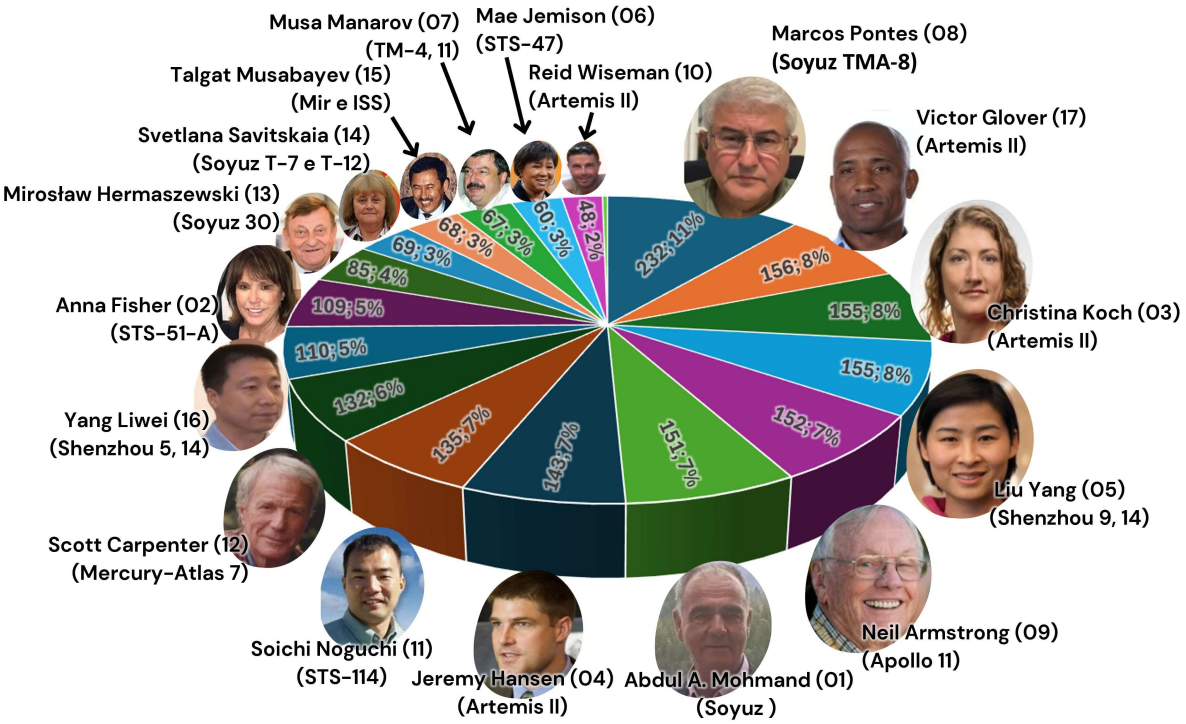

Figure 6. Q10 Accounting of the number of individuals who identified each of the persons presented as a potential astronaut or former astronaut.

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