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# Astronomy and visual disability: an analysis of publications in formal and non-formal education between 2013-2023

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## ABSTRACT

In this paper, we analyzed scientific publications related to astronomy education for people with visual disability in the SciELO, CAPES Periodicals, and Digital Library of Theses and Dissertations databases between 2013 and 2023. A total of 27 texts were found through the search with pre-established descriptors in Portuguese, English, and Spanish. Most of the texts were published less than five years ago, dated between 2020 and 2023, and are from works developed outside Brazil, published in English. Three categories emerged from the thematic analysis of these texts: 1) formal education in astronomy for people with visual disability; 2) accessible astronomy in non-formal education; 3) inclusion and accessibility strategies in planetariums. The results indicate modest growth of formal and non-formal education in astronomy for people with visual disability. There are works dedicated to developing technologies and strategies that favor the access and enjoyment of people with visual disabilities in the area of astronomy and benefit the understanding of specific content, historical-cultural issues, and their relationships with technology and innovation. The initiatives are being developed and adopted in the classrooms (mostly by teachers) and in scientific-cultural spaces and in science communication activities in which non-formal education takes place. However, while we identify actions and projects for inclusion in astronomy, we also demonstrate that the debate on the topic needs to be expanded and deepened in some aspects, such as teacher training and the active role of people with visual disability. Finally, there is a need to develop a greater volume of investigations and studies on education for this audience in planetariums and scientific-cultural spaces, especially in Brazil.
**KEYWORDS:** Science Education; Formal Education; Non-formal Education; Visual Disability.

# Astronomia e deficiência visual: uma análise de publicações na educação formal e não formal entre 2013-2023

**RESUMO**

Neste artigo, analisamos publicações científicas referentes à educação em astronomia para pessoas com deficiência visual nos bancos de dados SciELO, Periódicos CAPES e Biblioteca Digital de Teses e Dissertações entre os anos de 2013 e 2023. A partir da busca com descritores pré-estabelecidos em Português, Inglês e Espanhol, foram encontrados 27 textos. A maioria desses textos tem menos de cinco anos de publicação, sendo datados entre os anos de 2020 e 2023, e é oriunda de trabalhos desenvolvidos fora do Brasil, publicados em inglês. Três categorias emergiram da análise temática desses textos: 1) educação formal em astronomia para pessoas com deficiência visual; 2) astronomia acessível na educação não formal; 3) estratégias de inclusão e acessibilidade em planetários. Os resultados indicam crescimento, ainda singelo, da educação formal e não formal em astronomia para pessoas com deficiência visual. Há trabalhos se dedicando a desenvolver tecnologias e estratégias que favorecem o acesso e a fruição das pessoas com deficiência visual na área de astronomia e beneficiam o entendimento sobre conteúdos específicos do tema, questões histórico-culturais e suas relações com a tecnologia e inovação. Muitas iniciativas são desenvolvidas para aplicação em salas de aula (majoritariamente pelos professores) e em espaços científico-culturais e ações de divulgação científica em que acontecem a educação não formal. Contudo, ao passo que identificamos ações e projetos para a inclusão de pessoas com deficiência visual em astronomia, também demonstramos que o debate sobre o tema precisa ser ampliado e aprofundado em alguns aspectos, como na formação de professores e no protagonismo das pessoas com deficiência visual. Fica evidente, portanto, a necessidade do desenvolvimento de um maior volume de investigações e estudos sobre a educação para esse público em planetários e espaços científico-culturais, especialmente no Brasil.

**PALAVRAS-CHAVE:** Ensino de Ciências; Educação formal; Educação não formal; Deficiente da Visão.

## INTRODUCTION

Currently, astronomy is a topic included in official documents for Brazilian basic education, such as the National Curriculum Parameters (PCNs) and the National Common Curriculum Base (BNCC). For elementary school students, the subject is part of the area of Natural Sciences and consists of three thematic axes, distributed throughout the 1st to 9th grade, namely: “Matter and the Universe”, “Life and Evolution”, “Earth and the Universe”. Langhi and Nardi (2012) defend the importance of students in the early grades having contact with the subject, to awaken interest and make celestial phenomena something less mystical and more understandable. The content, however, appears in a fragmented way and is related to other areas of knowledge, for example: “Apparent movement of the Sun in the sky”; “The Sun as a source of light and heat”; “Cardinal directions”; “Calendars, cyclical phenomena and culture”; “Sun-Earth-Moon System”; “Climate” (Carvalho & Ramos, 2020). In high school, the area of Natural Sciences and Technology addresses the theme of astronomy within the axes: “Matter and Energy” and “Life, Earth, and Cosmos”. Students are expected to develop skills that enable them to analyze, argue, predict and understand models, theories and laws related to the evolution of living beings, the Universe and changes in the world (Carvalho & Ramos, 2020).

The subject is also present in non-formal education that takes place in scientific and cultural spaces, such as planetariums, observatories, science centers, and museums. These places have great didactic and pedagogical potential (Santos, 2019) and can provide multisensory experiences in addition to the content, enhancing science communication for diverse audiences. For Romanzini and Batista (2009), in each of these spaces, the way of presenting astronomy to the public is approached in different ways. The authors describe that science centers can present recreational activities or exhibitions, observatories allow their visitors to observe the sky using equipment (telescopes or binoculars), and planetariums are environments composed of domes where films about the sky, planets, and other celestial objects are projected. According to the authors, planetariums can include other activities, such as image exhibitions, lectures, observation of the sky with the naked eye or with optical instruments, computer simulations, games and activities, and courses (Romanzini & Batista, 2009). In this sense, the role of these spaces in both non-formal science education and science communication is evident, because they help different audiences participate in subjects related to science and technology (S&T), enhancing the understanding of their processes, reflections, opinion formation, and individual or collective social decision-making (Marranghello et al., 2018).

SAccording to Varano and Zanella (2023), making the science that is present in astronomy something accessible to different audiences is achieved through the search for equity, offering ways for people to be able, within their life experiences, skills, interests and abilities, to create their own meanings from what is presented to them, offering opportunities for interaction and expression. The authors developed the exhibition “Sense the Universe” that focused on recreating astronomical representations that are in a non-visible wavelength (e.g., radio) for galaxies and active nuclei, for example. Multisensory stimuli were created, exploring visual, auditory and tactile aspects, adapting the construction of meaning and thus establishing connections between the senses and what is being

represented. Their conclusions reinforce that exploring the senses is a "promising way to convey in a universal and effective way scientific and in particular astronomical concepts" to different audiences and, especially, to those with visual disability (Varano & Zanella, 2023).

Given the relevance of astronomy education for different audiences, it is important to investigate strategies aimed at accessibility and inclusion, focusing on the participation of people with disabilities. With an emphasis on Latin America, Abreu et al. (2019) dedicated themselves to carrying out an “Accessibility Diagnosis in Museums and Science Centers in Brazil and Latin America”. The study included a selection of Brazilian planetariums and observatories (N=15) where the authors identified that, in most cases, accessibility was related to physical aspects (ramps, elevators, access) and attitude issues (reception and welcome). However, there is evidence that there is still a lack of attention regarding communication accessibility – both at the internal level of institutions (e.g. offering assistive technology resources in exhibitions) and at the external level of communication with their audiences and potential visitors (e.g. providing information about the institution and its activities in an accessible format) (Abreu et al., 2019). The unavailabilities found in the study may create barriers to the participation of people with disabilities, especially those with visual disability.

When we specifically address people with visual disability, access to formal or non-formal astronomy education, at a planetarium or astronomical observatory, can be challenging because most initiatives rely on visual elements. This point is highlighted by journalist, influencer, and disability rights activist, Gustavo Torniero, who comments that there is a shortage of accessible material and content, with descriptions of images or tactile objects, for people with visual disability.

> As a whole, I have significant difficulties today, for instance, in accessing astronomy information. It's not that I want to be an astronomer, but I want to have access to images of space. I don't know what a rocket looks like these days, for example. I don't have access to images of space that are released quite regularly, because they lack accessibility. These themes are incipient in my life and I wish there were more description and audio description in this type of content (Torniero, 2024, p. 166).

It is possible to find initiatives that are concerned with the paradigm shift in favor of accessibility and inclusion and that aim to transform this perspective. For instance, some non-formal education spaces propose strategies aimed at visiting audiences, such as offering materials with scales of different sizes to represent the planets of the Solar System, using rope and spheres for people with visual disabilities (Lopes et al., 2020) or associating sounds of different instruments with the colors of the stars and, thus, representing the various existing constellations (Assis, 2020).

However, information about these initiatives, studies, and assessments still seems isolated and poorly articulated within the scope of the broader area of education.During the search for sources to develop this study, it was possible to find authors (Rodrigues et al., 2018; Pereira et al., 2021; Santos et al., 2021; Rio & Pereira, 2023) who have already mapped previous topics of astronomy and visual disability. In their surveys, they addressed the number of existing publications proposing a selection of works published in conferences, books, masters and doctoral dissertations in the field of teaching physics, natural sciences, technology, and teacher training, all originating from Brazil. In other words, the topic has been

debated in the sphere of physics teaching, still very focused on formal education, seeking ways to approach the content in an accessible and inclusive way in the classroom.

When we look at the volume of publications found by the authors, Santos et al. (2021) developed the survey based on the minutes and annals of conferences related to the area of science education in Brazil, with a specific focus on teaching astronomy to people with visual disabilities. The results reveal a considerable number of publications on astronomy in general: 935 articles between 2001 and 2019. However, when delving deeper into the topic of visual disability, the number drops to just 23 articles – 10 focusing on Basic Education and 13 on non-formal education. The study developed by Pereira et al. (2021) reports that in their searches they found a total volume of 182 publications on teaching physics to people with visual disabilities, including articles, masters and doctoral dissertations and books, from 2000 to 2018. Of all the works, however, only 29 dealt with the subject of astronomy and the resources to teach it to people with visual disabilities. These recent studies reveal that the number of works found within the 'visual disability', 'astronomy' and 'education' categories is still low.

In light of this scenario, aiming to articulate the knowledge produced and published regarding formal and non-formal education in astronomy focused on people with visual disability, it is important to find and map works, analyze their scenario and understand the paths and challenges addressed. Thus, we propose, in this study, to carry out a “state of the art” of the theme, encompassing articles, masters and doctoral dissertations published in Portuguese, English and Spanish.

## METHODOLOGY

In this study, the proposed approach can be defined as “state of the art”, since it involves mapping and analyzing publications in different languages, relating the main topics discussed here. Research with this type of definition seeks to identify contributions, possible gaps, their restrictions and identify innovative experiences in search of solutions to the problem investigated (Romanowski & Ens , 2006; Ferreira, 2002).

According to Romanowski and Ens (2006), this type of study has well-defined steps, such as choosing descriptors to direct searches, databases, criteria used to select the material, its collection, reading, organization for writing the study, and preliminary conclusions. Thus, when we began the mapping, we conducted a search for publications addressing the topics of astronomy, non-formal education, accessibility, and visual disability based on predefined descriptors. We detail each stage of the study below.

### DESCRIPTORS



To guide the searches for this study, we chose to use some descriptors that are related to the topics of interest. The chosen descriptors combine the subjects, thus aiming to ensure that we have greater success in finding works related to what we are looking for. Initially, we took as a basis the descriptors in Portuguese, which were translated into English and Spanish, namely: 1) descriptors in Portuguese:

planetários acessíveis; planetários inclusivos; planetários e deficiência visual; planetários adaptados; planetários táteis; educação em planetários; 2) descriptors in English: accessible planetariums; inclusive planetariums; planetariums and visual impairment/visual disability; adapted planetariums; tactile planetariums; planetarium education; 3) descriptors in Spanish: planetarios accesibles; planetarios inclusivos; planetarios y discapacidad visual; planetarios adaptados; planetarios táctiles; educación en planetarios.

When we started searching the databases and doing a first round of results, we saw that the initial descriptors did not offer a large number of publications, which was insufficient to develop the desired analysis. From this, it became clear that there was a need to expand the descriptions to the three languages, thus adding: 1) descriptors in Portuguese: astronomia acessível; astronomia inclusiva; astronomia e deficiência visual; astronomia adaptada; astronomia tátil; 2) descriptors in English: inclusive astronomy; astronomy and visual impairment/visual disability; adapted astronomy; tactile astronomy; 3) descriptors in Spanish: astronomía accesible; astronomía inclusiva; astronomía y discapacidad visual; astronomía adaptada; astronomía táctil.

The main interest was to find results involving the subject “Planetariums” or “Astronomy” related to “Education” and “Visual disability”, therefore the first two words were kept in all searches. By expanding the descriptors, it was then possible to have substantial results within the expected range to begin our analysis. In total, 33 descriptors were utilized, 11 for each language.

## DATABASES

To search for publications, some databases that are most used and have the greatest credibility to carry out researches in the area of education and science communication in Brazil were selected, they are: Scientific Electronic Library Online (SciELO), Periódicos da Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) e a Biblioteca Digital Brasileira de Teses e Dissertações (BDTD).

SciELO is an excellent tool for international searches – in addition to covering Latin America (Argentina, Brazil, Chile, Colombia, Cuba, Costa Rica, Venezuela, Bolivia, Peru and Uruguay), it also has articles from Europe and South Africa. The CAPES journal and the BDTD are repositories that maintain academic productions from Brazilian institutions, providing public access, in several areas of knowledge. Given that these databases are well-regarded and contain a substantial volume of publications, they were selected for the survey.

## CRITERIA USED FOR MATERIAL SELECTION

To select the publications, our initial criterion was to correlate the titles with the subjects we aimed to investigate. Once a topic was identified as relevant to what we wanted to investigate, the abstract of the paper was read in full to confirm the hypothesis. Finally, the papers that directly addressed visual disabilities were selected. Duplicates across multiple databases were considered only once.

## COLLECTION

To guide the search in the databases, a 10-year time frame was defined, considering publications between 2013-2023. This time frame was chosen because it preceded the enactment of the Brazilian Inclusion Law (LBI) of 2015, which covers several basic rights of people with disabilities, such as education, health, leisure, work, housing, culture, scientific advances, among others (LBI, 2015). This period also coincides with the intensification of debates, higher education courses specialized in cultural accessibility were created, and there was also an increase in publications on the subject (Norberto Rocha et al., 2017). Additionally, it is interesting to search for more recent works that portray advances on the subject.

## READING AND ORGANIZATION

The articles were selected, for the most part, after reading the abstract to identify the connection between the topics covered. After pre-selection, the texts were fully read to validate the selection and identify recurring themes in order to create emerging categories of the material. To organize, the selected material was listed according to the database in which it was found, type of text, author(s), place of publication, title of the text and descriptor(s). After completing the organization, the results were categorized. This categorization was based on the principle that the texts found addressed topics explicitly related to astronomy education (formal and non-formal), adaptation of materials aimed at astronomy and, finally, strategies that non-formal spaces develop to welcome people with visual disability.

To analyze and identify trends, we categorized based on thematic analysis. This type of analysis allows us to provide a detailed description of a given topic in order to find repeated patterns of meaning. Thematic analysis shows a certain independence from the constraints of the theoretical framework. As described by Braun and Clarke (2006), it is not defined solely by theory, but is an analytical character, being directly associated with the text, composed of criteria defined by themes linked to the literature analyzed or pre-established by the researcher.

Finally, we selected for discussion some texts that represent their categories.a discussão alguns textos que representam suas categorias.

## DISCUSSION AND RESULTS

The total of 27 papers identified in the search, in the three languages, are presented in Table 1. Most of the texts are in English (17), followed by Portuguese (9) and Spanish (1). Most of these texts are in the form of articles (24), followed by two dissertations and one thesis. The databases host different numbers of texts: Scielo (1), CAPES (23), BDTD (3).

**Table 1:**

*Texts identified by database*

| Code | Authorship | Journal (article)/ type of publication (thesis; dissertation) | Title |
|---|---|---|---|
| **Scielo** | | | |
| T1 | Almeida, M. S. et al. | Revista Brasileira de Ensino de Física | Construção de uma Maquete do Sistema Solar com Controle de Temperatura para Alunos com Deficiência Visual (2020) |
| **CAPES** | | | |
| T2 | Rio, B. G. et al. | Revista Internacional de Ciências | Ensino de astronomia para alunos com deficiência visual no atendimento educacional especializado (2023) |
| T3 | Argudo-Fernández, M. | Revista Mexicana de Astronomía y Astrofísica | Astronomía inclusiva (2022) |
| T4 | Nunes, R. C. & Dutra, C. M. | Revista Vivências | Oficina de astronomia inclusiva para professores do atendimento educacional especializado (2020) |
| T5 | Rizzo, A. L. et al. | Revista Brasileira de Pesquisa em Educação em Ciências | Ensino do Sistema Solar para alunos com e sem deficiência visual: proposta de um ensino inclusivo (2014) |
| T6 | Waghorn, E. L. | Revista Mexicana de Astronomía y Astrofísica | Online astronomy for BVI people (2022) |
| T7 | Beckers, I. E. et al. | Revista Educação Especial | O processo de ensino-aprendizagem de Ciências em turmas com alunos deficientes visuais: percepções de professores (2014) |
| T8 | Jesus, D. S. de & Anastácio, S. A. F. | Revista de estudos em Educação e Diversidade | Divulgação da astronomia para o público vidente e com deficiência visual: experiência em um espaço não formal de ensino/aprendizagem (2022) |
| T9 | Cacace, G. & Pereyra, A. | Revista Mexicana de Astronomía y Astrofísica | Astronomy without borders: planetario accesible (2022) |
| T10 | Zanazzi, A. et al. | Revista Mexicana de Astronomía y Astrofísica | A permanent and inclusive exhibition at inaf arcetri astrophysical observatory (2022) |
| T11 | Harrison, C. et al. | Astronomy and Geophysics | Audio Universe: Tour of the Solar System (2022) |

| Code | Authorship | Journal (article)/ type of publication (thesis; dissertation) | Title |
|---|---|---|---|
| T12 | Grice, N | Revista Mexicana de Astronomía y Astrofísica | Accessible astronomy: how to adapt activities for blind and visually impaired learners using low cost materials (2022) |
| T13 | Zanella, A. et al. | Nature Astronomy | Sonification and Sound Design for Astronomy Research, Education and Public Engagement (2022) |
| T14 | Arcand, K. | Revista Mexicana de Astronomía y Astrofísica | Chandra's accessible universe: from sight to sound touch (2022) |
| T15 | Noel-Storr, J. & Willebrans, M. | Nature Astronomy | Q&A: Accessibility in Astronomy for the Visually Impaired (2022) |
| T16 | García-Benito, R. & Pérez-Montero, E. | Revista Mexicana de Astronomía y Astrofísica | Painting graphs with sounds: cosmonic sonification project (2022) |
| T17 | Usuda-Sato, K. et al. | Revista Mexicana de Astronomía y Astrofísica | Dissemination of the “touch the universe” tactile exhibition (2022) |
| T18 | Quiroz, A. R. et al. | ArXiv | Inclusive Astronomy in Peru: Contribution of Astronomy Teaching for Visually Impaired People (2021) |
| T19 | Fuentes-Muñoz, C. & Paredes-Sabando, P. | Revista Mexicana de Astronomía y Astrofísica | Dedoscopio: an inclusive project dedicated to bring tactile astronomy talks (2022) |
| T20 | Bonne, N. J. et al. | Astronomy & Geophysics | Tactile Universe makes outreach feel good (2018) |
| T21 | Casado, J. et al. | American Journal of Astronomy and Astrophysics | A New Approach to Sonification of Astrophysical Data: The User Centred Design of SonoUno (2022) |
| T22 | Deandra, A. et al. | Revista Mexicana de Astronomía y Astrofísica | An application of sonification as an alternative for the accessibility of astronomical images to the visually impaired (2022) |
| T23 | Pérez-Montero, E. et al. | Sociedad Española de astronomía | A tactile model of the night summer northern sky for the teaching of astronomy to the BVI (2022) |
| T24 | Tamayo, J. P. U. et al. | Revista Científica | Astronomía ConTacto: Una Estrategia para la Divulgación de la Astronomía entre Personas con Discapacidad Visual (2019) |
| **Biblioteca Digital Brasileira de Teses e Dissertações** | | | |
| T25 | Santos, A. L. | Dissertação em | Astronomia acessível no Município de Feira |

| Code | Authorship | Journal (article)/ type of publication (thesis; dissertation) | Title |
|---|---|---|---|
| | de J. dos P. | Astronomia | de Santana: um olhar voltado para a pessoa com deficiência visual (2020) |
| T26 | Rocha, R. G. C. | Dissertação Ensino de Ciências da Natureza | Ensino de astronomia na perspectiva da inclusão de deficientes visuais em aulas de física do ensino médio (2016) |
| T27 | Rodrigues, F. M. | Tese em Educação para a Ciência/ Ensino de Física | O céu como tema gerador para a educação inclusiva em Astronomia: desafios e possibilidades a partir da cosmopercepção de estudantes com deficiência visual (2020) |

*Fonte: Authors (2024)*

The high number of descriptors used for this research made the search scope broad. However, despite the diversity desired, only a specific group of descriptors generated the results. Of the 33 descriptors used in the search, 12 had the highest occurrence: astronomia inclusiva (8), accessible astronomy (4) e inclusive astronomy (4). Other descriptors generated few or no results, such as “Planetários adaptados” and “Planetários e deficiência visual”. This data shows that the most used terms in the papers involve “astronomy” and “inclusion” and may highlight the lack of publications related to the term “planetarium” combined with “inclusion” or “accessibility”.

We identified a greater volume of publications between 2020 and 2023, with a total of 22 works, and only five works from 2014 to 2019. This may demonstrate that debates on the topic may have been intensifying in recent years. We also observed, by reading these works in full, that the locations in which the studies were conducted are varied: Latin America (Brazil, Peru, Argentina, Colombia, Mexico, Chile), Europe (United Kingdom, Spain, Netherlands, Italy), Asia (Japan) and North America (United States). Most of the texts (18) are foreign and only a third of them (nine) are Brazilian texts. These data may reveal that there is a global movement in search of strategies to make astronomy more accessible.

Another notable fact is that a large part of the publications are in journals directly related to astronomy, science or teaching. In particular, we see a large presence of the Mexican Journal of Astronomy and Astrophysics, responsible for publishing the various works presented at the “2nd Workshop on Astronomy Beyond the Common Senses for Accessibility and Inclusion”, carried out in 2021. The masters and doctoral dissertations found are linked to postgraduate programs in teaching/education in science or astronomy.



## CATEGORIZATION OF FOUND MATERIAL

Through the thematic analysis, three categories emerged from the texts: 1) astronomy for people with visual disability in formal education; 2) accessible

astronomy in non-formal education; 3) inclusion and accessibility strategies in planetariums (Table 2).

The majority of works focused on studies that seek adaptations of materials for astronomy, especially aimed at non-formal education, totaling 15 of the 27 articles.

**Table 2:**

*Organization of papers by categories*

| | Astronomy for people with visual disability in formal education (N=7) | Accessible astronomy in non-formal education (N=15) | Inclusion and accessibility strategies in planetariums (N=5) |
|---|---|---|---|
| **Nº** | **Reference code** | | |
| 1 | T2 | T1 | T11 |
| 2 | T27 | T25 | T10 |
| 3 | T26 | T3 | T8 |
| 4 | T4 | T12 | T9 |
| 5 | T5 | T24 | T17 |
| 6 | T7 | T6 | - |
| 7 | T23 | T13 | - |
| 8 | - | T14 | - |
| 9 | - | T15 | - |
| 10 | - | T16 | - |
| 11 | - | T18 | - |
| 12 | - | T19 | - |
| 13 | - | T20 | - |
| 14 | - | T21 | - |
| 15 | - | T22 | - |

*Fonte: Authors (2024)*

## Astronomy for People with Visual Disabilities in formal education



The seven texts that address “Astronomy for people with visual disability in formal education” demonstrate that astronomy is a necessary area in science teaching. Within this category, the texts address strategies and activities for the education of people with visual disabilities, largely developed by teachers, using,

for example, low-cost tactile or 3D materials. Another issue addressed is the discussions regarding teacher training for these activities.

Rodrigues (2020) reports that it is essential to understand that there are different school contexts and this can influence the way the science curriculum will be taught in the classroom. This context is further strengthened when the initial training of teachers is investigated and a gap is found on some subjects, including astronomy. If the inclusion of students with visual disabilities is considered, teachers' resistance increases even more, based on the idea that science is approached visually (Rodrigues, 2020). The author's explanation is in line with the research carried out by Rio et al. (2023) in which it was found, within a N=12 investigated in a Pedagogical Support Center for people with visual disabilities, that 60% of science teachers claimed they have never done activities related to astronomy for people with visual disability, while 40% stated that they occasionally work with the content. The majority, around 80% of participating teachers, say that 3D or tactile material is necessary for working with this type of audience, reinforcing the need for more studies, research and production of materials to provide adequate support to people with visual disability (Rio et al., 2023).

The study led by Beckers et al. (2014) presents a perspective on the actions of teachers with specialized training in special education. In their analysis, the authors bring up issues related to teacher training that, although appropriate to the teaching-learning model, reflects a gap in science education present in undergraduate courses and the lack of postgraduate courses that work with astronomy content. The methodology and use of objects were also investigated, where it was found that the classes taught by the teachers are based on visual elements (videos, shadows), with no use of adapted materials identified, which hinders the participation of students with visual disabilities. As a result, the authors note that a sequence of factors can hinder inclusive education, such as inexperience, the existence of a certain gap in training, lack of support or materials for classroom work (Beckers et al., 2014).

Through the searches in this section, it is possible to find works that address alternative ways of including students with visual disabilities in astronomy classes, either by building a tactile model (Rizzo et al., 2014) or by developing a didactic-methodological sequence (Rocha, 2016). The research by Rizzo et al. (2014) brings considerations about the research subjects, revealing fundamental issues related to the lack of use of multisensory materials throughout the school experience, the importance of the teacher understanding the visual disability of their student, and the need to explore other senses when approaching content related to physics and astronomy. The work developed by Rocha (2016) proposes an approach that brings students with disabilities closer to the concepts of physics, especially the emergence of the Universe, through different dynamics (video, tactile experiment, music), creating a more integrative didactic-methodological sequence for all students. In both studies, we see that much is expected of teachers, adding new demands and requiring qualified professionals to present appropriate methodological proposals. Once again, the need to modernize undergraduate course curricula to train teachers who are qualified in relation to inclusion becomes clear (Rizzo et al., 2014).

In this sense, Rodrigues (2020), based on several authors, describes some reasons listed by teachers for not teaching astronomy: lack of time to deal with all

subjects related to science; lack of mastery in teacher training; interdisciplinarity; errors in textbooks. It is worth noting, however, that the education in astronomy presented by the author addresses the "opportunity for a global vision of the development of human knowledge in relation to the Universe that surrounds us", the "development of useful skills in all branches of knowledge and everyday science", "offers opportunities for activities that also involve outdoor practices and that do not require expensive materials or laboratories", among others (Rodrigues, 2020). The last motivation is interesting because it provides the opportunity to intertwine formal and non-formal education, exploring other spaces beyond the classroom and the contributions that multiple approaches can generate for students, especially those with visual disabilities, generating interpretations and attribution of meanings.

## Accessible astronomy in non-formal education

There is a growing number of tactile, auditory and/or multisensory resources that can explore the senses beyond vision in non-formal astronomy education for people with visual disability (Nepomuceno & Zander, 2015). The discussion about these methods, strategies and resources are the focus of the texts found in the category defined as "Accessible astronomy in non-formal education", which covers the largest number of texts in the survey, a total of 15.

When analyzing the texts, we observed a trend: the search for testing methodologies and experiences of development or application, validation and evaluation of adapted teaching materials and ways to reduce possible barriers in education and the promotion of inclusion. Thus, the initiatives to make astronomy accessible and at the same time keep the public engaged, especially in scientific and cultural spaces and scientific communication actions, were predominantly two: 1) the construction of materials that represent the elements found in astronomy (galaxies, planets, stars, etc.) and 2) representation through the use of audio/sound.

The Chilean work of Argudo-Fernández (2022) exemplifies this category. The text presents the "Inclusive Astronomy" project, supported by astronomers aiming to overcome barriers and develop new methods to communicate this science. The author describes that there are great challenges in communicating with people with visual disabilities about astronomy without the help of images. Some strategies adopted in the project include using tactile models, developed in the "AstroBVI" project, combined with communication of simple terms – formation of stars, planets and asteroids – until reaching more complex terms such as galaxies (Argudo-Fernández, 2022). "AstroBVI", from the English blind and visually impaired (BVI), is a product composed of 3D tactile images of galaxies built in partnership with the project The Tactile Universe. In workshops that aim to work on astronomy themes based on the participants' knowledge, the product is applied to understand the best way to manage the session. The applications made with "AstroBVI" demonstrate that the public with visual disabilities actively engages in the debate and that new knowledge emerges through questions and discussions. Argudo-Fernández (2022) concludes the work by stating that "Inclusion is a daily work. We can all work to create a welcoming and receptive environment around us" (p. 19).

Another strategy found to make astronomy accessible is related to the use of sounds. According to Zanella et al. (2022), sound is multidimensional and uses multiple parameters (timbre, tone, volume, location, etc.), making it possible to perceive and receive different stimuli at the same time. García-Benito and Pérez-Montero (2022) present in their study the concept of "sonification" as a technique that uses data to generate sounds, examples being: assistance in parking cars, deleting the trash folder (auditory icons), email alerts or operating system shutdown (earcons) (García-Benito & Pérez-Montero, 2022). Using sonification, the authors describe the project called "COSMONIC", developed to represent any type of data in several acoustic dimensions, which can be used to illustrate astrophysics concepts. This project has been implemented in partnership with the "Astroaccesible" project, dedicated to promoting inclusive astronomy for people with visual disability and low vision. Another example of the use of sonification is in the work of Deandra et al. (2022), in which the same technique is used for images, instead of data. The dynamic consisted of transforming the image into sound, based on the shapes of the desired object, that is, representing the shapes and positions of the object in a way analogous to the tone of the sound. After creation, these shapes (lines and curves), which were sonified in high-relief material, are presented to the participants. The text indicates the success of the initiative, highlighting that sonification can be a useful tool for the inclusion of audiences with visual disability and can also be presented to a wider audience (Deandra et al., 2022; García-Benito & Pérez-Montero, 2022).

## Inclusion and Accessibility Strategies in Planetariums

The mapping also found five articles that fit into the category "Inclusion and Accessibility Strategies in Planetariums". We observed that these activities can be planned by people outside planetariums and applied to them, for research purposes, or through internal initiatives and institutional policies that aim to reduce barriers and include different audiences.

In order to present an overview of the actions that have been developed by or for planetariums, we selected articles from this mapping that deal with the topic and can be considered, based on our analysis, success stories due to the way in which they conducted and applied accessibility strategies. The planetariums that carry out these actions presented in the texts found are in Argentina (Cacace & Pereyra, 2022), Japan (Usuda-Sato et al., 2022) and the United Kingdom (Harrison et al., 2022).

The article by Cacace and Pereyra (2022), entitled " Astronomy without borders: Planetario Accesible", describes the accessibility-focused work carried out at the Planetarium of Buenos Aires, Argentina. According to the authors, the planetarium aims to stimulate learning opportunities, awaken motivation and interest in science, and be a reference for science communication and popularization of astronomy. To be able to embrace diverse audiences, one strategy is to try to understand their needs and particularities, creating specific activities that meet their demands and make them feel welcome in the space.

The approach adopted by the planetarium that has been yielding results is to work with "layers of understanding" and thus meet different learning and experience needs. Cacace and Pereyra (2022) state that "in cultural spaces, such as

museums and planetariums, visitors are considered their most important asset". According to the authors, for an institution to be inclusive, it must constantly transform itself. Thinking of new strategies, methods and paying attention to its audience is a way to meet individual differences and contribute to inclusion in education and non-formal spaces. The authors argue that understanding diversity cannot be seen as an obstacle, but as an opportunity to enrich the environment and everyone who is part of it (Cacace & Pereyra, 2022).

Regarding adaptations, the authors mention physical changes such as: ramps, elevators, accessible bathrooms and free access for people in wheelchairs in the presentation room. For the communication part, there are: magnetic rings, tactile panels with astronomical information and the expansion of the Wi-Fi network. Also thinking about the attitudinal part, the space promotes frequent actions with the team aimed at education, training and counseling, keeping its members always updated and with the necessary tools for a better reception and hospitality, making the planetarium a welcoming place. Among the adaptations for people with visual disabilities, the authors present the adaptation of the show "From Earth to the Universe" that has tactile material with contrasting colors. In it, the concept of the colors of the stars is demonstrated with the direct relationship of their surface temperature (blue, yellow or red are more or less hot, respectively), making an analogy with sound waves and light waves. The authors explain that "The hottest and most energetic stars have a higher-pitched and shrill sound, and are bluish. On the contrary, the less hot ones are reddish and have a more muffled and low sound." (Cacace & Pereyra, 2022, p.41). Finally, Cacace and Pereyra (2022) reinforce that the planetarium is a space designed for everyone, which increases its social, leisure and learning value. Making its structure, content and communication accessible is making astronomy a subject that is attainable by everyone, building an accessible planetarium and astronomy without borders.

The work "Dissemination of the "Touch the Universe" tactile exhibition" by Usuda-Sato et al. (2022) presents how the use of three-dimensional printing to produce 3D tactile materials has helped to improve interaction and communication in astronomy for people with visual disability. The authors list several planetariums around the world that use the technique applied to projects. Among them are: "A Touch of the Universe", developed in Spain with representations of the Moon, Mars and other planets; "Tactile Universe", from the United Kingdom, which prints a galaxy; NASA, in the United States, which has a website with several models of celestial bodies, spacecrafts and telescopes available for 3D printing. In Japan, the team at the National Astronomical Observatory (NOAJ) created a representation of the Subaru Telescope and developed two prototypes based on consultation with people with low vision and a teacher with disabilities.

The project "Touch the Universe" is made up of four institutions with different strengths, namely: 1) NOAJ, characterized by an institution linked to research, which can provide 3D printed models; 2) Japan Braille Library (JBL), specialized in visual disabilities, enabling the spread of information and tips on how to develop an exhibition and communicate with this audience; 3) Akashi Municipal Planetarium and 4) the Sendai Astronomical Observatory – made up of specialists in communicating astronomy who have experience with people with disabilities. In the report by Usuda-Sato et al. (2022), it is clear that the project generates great

interest from other scientific spaces that wish to incorporate the tactile material into their exhibition, since those responsible for the initiative receive several reservation requests. The idea is for the material to become increasingly popular nationally. Furthermore, the creators' expectation with this initiative is to bring comfort and confidence to the team of these spaces so that communication with people with visual disability or low vision is increasingly accurate, contributing to a more inclusive and accessible astronomy.

Harrison et al. (2022) describe in “Audio Universe tour of the Solar System: Using sound to make the Universe more accessible” an adaptation of a show about the Solar System that was designed to be presented in planetariums or other locations, such as at home. The main objective of the initiative called “Audio Universe” is to make content related to astronomy accessible regardless of people’s visual ability (Harrison et al., 2022).

The pilot project on the Solar System was designed to be a social and educational experience using sound stimuli, which could be reproduced in a planetarium dome or on flat screens. Harrison et al. (2022) explain that the soundtrack for the entire show was created before the visual components. To ensure the sounds made sense to the audience, the project involved consultations with individuals with visual disabilities, including adults, children, astronomers, and teachers who specialized in working with this group. In addition, astronomers with visual disabilities were included as part of the development team. All the initiatives mentioned by Harrison et al. (2022) contribute positively to the communication part working effectively with the audience. For all the effort to be successful, there is a prior contextualization to be done, where lights are projected and their color is “translated” into sound. Harrison et al. (2022) explain as an example that the definition of sound for the Sun brings elements that refer to fire, giving the sensation of burning objects and, like so, a pattern of musicality is followed for all other planets. The “Audio Universe” experience is capable of explaining the magnitude of the stars (the brightest ones sound first and the faintest ones last) and even their positioning in the sky (stars in front of the observatory have their sound reproduced on front speakers). Finally, Harrison et al. (2022) emphasize that it is essential to have groups collaborating in the construction of the project, actively participating in decision-making and contributing to clear communication. There is also the desire that multisensory techniques be considered as a recurring practice in other spaces when talking about astronomy.

## FINAL CONSIDERATIONS

In this study, we mapped 27 different papers that address formal and non-formal education in astronomy for people with visual disabilities published between 2013 and 2023. The studies found in Portuguese, English and Spanish were organized into three main themes: 1) Astronomy for people with visual disability in formal education; 2) Accessible astronomy in non-formal education; 3) Inclusion and accessibility strategies in planetariums.



Most of the texts were published less than five years ago – dated between 2020 and 2023 – and originated from studies developed outside Brazil. There are 18 foreign texts and nine Brazilian ones, both with a greater flow after 2020. These results indicate a still modest growth in formal and non-formal education in astronomy for people with visual disabilities.

Most of the works found in the category “Astronomy for people with visual disability in formal education” refer to actions and materials designed, developed and presented, in large part, by teachers in an effort to bridge the gap between teaching and students with visual disabilities in relation to the subject of astronomy. Regarding the strategies created for classroom use, the most commonly cited involve the use of low-cost tactile or 3D materials, often designed and built by the teachers themselves to try to meet the needs of the diversity of students. It is also relevant to reflect on an issue raised by the authors of this block with regard to teacher training. This debate involves planning and preparing teachers to work with subjects related to astronomy, especially in an accessible way. In our readings, we see that this is still a challenge for professionals to address various aspects of astronomy. As previously mentioned, working on this topic in Elementary and High School is provided for in the BNCC, guidelines and other official education documents in Brazil. We therefore understand that we need to invest in training and teaching practices to work on the topic and make it accessible to students with disabilities.

The analysis of texts focused on practices in non-formal education spaces is present in the category “Accessible Astronomy in Non-Formal Education”. The articles found show a trend: based on research, they seek to test methodologies and strategies and validate produced materials, as a way of reducing possible barriers in astronomy education. The research developed and applied in non-formal education spaces, such as museums, astronomical observatories and scientific communication actions, demonstrates great potential to provide and promote access and accessibility to knowledge.

It is also clear that we cannot view formal education separately from non-formal education. Although each has its own classifications and definitions, widely debated by numerous authors in the field of education, we know that human experiences are not isolated and much less constructed in a unique way. Understanding that there are advantages to working with both types of education ensures a better construction and evolution regarding teaching and learning, since by proposing different forms and approaches, we can present and explore content in different ways, feelings and knowledge, collaborating mutually in this process.

The last area, defined as “Inclusion and accessibility strategies in planetariums”, provided an overview of the actions developed by planetariums in various places around the world. Based on the work found, we were able to identify how the teams at these scientific and cultural spaces have prepared themselves, searching for techniques, materials, and ways to improve their accessibility strategies to welcome the public with visual disabilities in an accessible and inclusive way.

Two points stand out in these cases. The first is that, most of the time, the initiatives rely on the collaboration of people with visual disabilities for their validation – which increases the chances of success in promoting accessibility and inclusion. The second point concerns the leading role of people with visual disability in these projects and research. Although the texts report that they collaborate with people with visual disability, mainly to validate and test products and strategies developed, it is not possible to know whether the authors and researchers are people with visual disability. Moreover, little is read about the opinions and experiences of this audience in relation to the activity provided. The

texts do not address their speeches, expressions, group conversations, interactions, emotions, etc. This makes us question how engaged in the research and protagonists of their own stories people with disabilities are. Beyond validating new strategies and writing about the successes achieved, we emphasize that it is essential to have people with visual disabilities as agents of projects and studies and to highlight their experiences, recording their voices.

Finally, we found studies dedicated to developing technologies and strategies – especially related to sounds and touch – that favor access and enjoyment of astronomy for people with visual disabilities and benefit their understanding of specific content on the topic, historical and cultural issues, and their relationships with technology and innovation. These initiatives are being explored and adopted in the classroom (mostly by teachers) and in scientific and cultural spaces and scientific communication activities where non-formal education takes place. However, while we identified actions and projects for inclusion in astronomy in Brazil and abroad, we also demonstrated that the debate on the topic needs to be expanded and deepened in some aspects. Among these aspects, urgent issues stand out, such as training teachers to work with astronomy in an accessible way and the active participation of people with visual disabilities in all processes that interest them.

This study clearly demonstrates the need for increased research and studies on astronomy education for people with visual disabilities, especially in Brazil. Ultimately, we hope to contribute to formal and non-formal education aimed at this audience and to stimulate actions, initiatives, strategies in planetariums and other scientific-cultural and scientific communication spaces, as well as we hope to inspire further research and publications on this important subject.

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