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Scientific literacy at the UEPG museum of natural sciences: reflections and transformations in academic trajectories

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ABSTRACT

Scientific literacy fosters the understanding of the role of science in society, making it essential for the development of critical citizenship. This study investigated the contributions of the extension projects “Geodiversity in Education” and “UEPG Museum of Natural Sciences” to the education of undergraduate students from various programs, focusing on the scientific literacy promoted through the projects’ activities. The research followed a qualitative, exploratory approach and was conducted in a non-formal education setting, emphasizing participant interaction with geodiversity and biodiversity collections, engagement in mediation processes, and participation in science communication activities in the field of natural sciences. The objective was to analyze how participation in the projects contributed to the development of scientific literacy among the students, based on the Structuring Axes of Scientific Literacy. Data were generated through a semi-structured questionnaire and analyzed using Content Analysis methodology. The results indicated improvements in the understanding of scientific concepts related to the natural sciences, in the development of critical thinking, and in recognizing the importance of science to society and the environment. Another relevant aspect was the increased awareness of the role of science in addressing social and environmental issues. It is concluded that non-formal education spaces, such as science museums, promote scientific literacy, integrate theory and practice, and encourage a critical perspective on science and its social impact.

KEYWORDS: Scientific literacy; Science museums; UEPG Museum of Natural Sciences; Extension; informal education; Social impact.

Alfabetização científica no museu de ciências naturais da UEPG: reflexões e transformações nas trajetórias acadêmicas

RESUMO

A alfabetização científica suscita a compreensão do papel da ciência na sociedade, o que a torna essencial para o desenvolvimento de uma cidadania crítica. Este estudo investigou as contribuições dos projetos de extensão “Geodiversidade na Educação” e “Museu de Ciências Naturais da UEPG” para a formação de alunos de diversos cursos de graduação, com foco na alfabetização científica promovida pelas ações dos projetos. A pesquisa foi guiada pela abordagem qualitativa, de cunho exploratório, e realizada em ambiente de educação não formal, com ênfase na interação dos participantes com acervos de geodiversidade e biodiversidade, na atuação em processos de mediação e em atividades de divulgação na área de ciências naturais. O objetivo foi analisar como a atuação nos projetos contribuiu para o desenvolvimento da alfabetização científica dos participantes, com base nos Eixos Estruturantes da Alfabetização Científica. Para gerar as informações e proceder às análises, foram utilizadas as diretrizes fornecidas pela metodologia de Análise de Conteúdo, partindo de dados gerados por meio de um questionário semiestruturado. Os resultados apontaram ganhos na compreensão de conceitos científicos ligados às ciências naturais no desenvolvimento da reflexão crítica e no reconhecimento da importância da ciência para a sociedade e o meio ambiente. Outro aspecto a ser destacado é a maior conscientização sobre o papel da ciência na resolução de questões sociais e ambientais. Conclui-se que espaços de educação não formal, como museus de ciências, promovem a alfabetização científica, integram teoria e prática e incentivam uma visão crítica sobre a ciência e o seu impacto social.

PALAVRAS-CHAVE: Alfabetização científica; Museus de Ciências Naturais da UEPG; Extensão; Educação não formal; Impacto social.

INTRODUCTION

Scientific literacy, beyond the learning of specific scientific content, encompasses a set of skills, attitudes, and knowledge that favor a better understanding of the role of science in society and its use in solving everyday problems. Thus, scientific literacy stimulates the development of critical thinking and can contribute to the formation of individuals who question, reflect, and debate scientific issues, considering the applications of science in various aspects of social life.

Different educational environments, from formal education spaces, such as schools, to those promoting non-formal education, such as museums, contribute to the dissemination of scientific literacy. These institutions offer educational scientific experiences by creating opportunities for learning to occur interactively, dialogically, and in a context that includes sociocultural and natural elements and phenomena.

The Museum of Natural Sciences at the State University of Ponta Grossa (MCN-UEPG), through its extension and research activities, seeks to promote scientific literacy in its exhibitions and in the narratives presented by its mediators. Before the establishment of the museum space, educational and extension activities were developed at UEPG through two extension projects: “Geodiversity in Education” (2011), from the Department of Geosciences, and “Zoology in Focus” (2014), from the Department of General Biology. Later, the merging of the collections from both projects led to the creation of the MCN.

Currently, the MCN promotes extension and research activities linked to the Geography and Biological Sciences teaching programs, involving faculty and students who act as researchers and mediators (scholarship holders and/or volunteers). Marandino, Kauano, and Martins (2022) highlight that natural science museums, in addition to being influenced by the field of museology, are impacted by areas such as Physics, Biology, Chemistry, and Geosciences, as well as by discussions in education, communication, and scientific dissemination.

Furthermore, museums develop actions aimed at different audiences, combining cultural and scientific experiences with reflections on everyday issues and providing access to scientific knowledge in a contextualized and practical manner (Pscheidt & Lorenzetti, 2020).

Based on these assumptions, research was conducted with 45 students who participated in the extension project “Geodiversity in Education” (2011-2019) and activities at the MCN-UEPG (2020-2024), developed under an extension project bearing the same name as the museum. The students come from the Geography and Biological Sciences teaching programs, the Geography and Tourism bachelor's programs. The objective was to analyze possible contributions to the development of scientific literacy among mediators and researchers during their participation in related extension projects.

The investigation adopted a qualitative, exploratory approach, with data and information obtained through a semi-structured questionnaire, analyzed and interpreted according to the guidelines of Content Analysis (Bardin, 2020), which allows for understanding the meanings that subjects attribute to their social and historical practices. For this purpose, the units of analysis in this investigation were

based on a categorization defined a priori, supported by the Structuring Axes of Scientific Literacy: (a) basic understanding of fundamental scientific terms, knowledge, and concepts; (b) understanding the nature of science and the ethical and political factors surrounding its practice; and (c) understanding the relationships between science, technology, society, and the environment, as presented by Sasseron and Carvalho (2008, 2011) in their literature review on the topic. To reveal the "core meanings" of the interviewees' statements analyzed according to the theory underpinning this research, the unit of record "theme" was used.

THE "GEODIVERSITY IN EDUCATION" PROJECT AND THE UEPG MUSEUM OF NATURAL SCIENCES

The extension project "Geodiversity in Education", initiated in 2011, developed its activities for about eight years at the Uvaranas campus of the UEPG. Composed of undergraduate Geography students and faculty from the Department of Geosciences, its main objective was to disseminate geoscientific knowledge, with emphasis on understanding the evolution and history of the Earth in dialogue with its geological heritage. To this end, permanent exhibitions of geodiversity elements were created for the general community and, especially, for school groups, displaying rocks, minerals, fossils, and meteorites in corridors and passage areas of the campus (Figure 1).

Figure 1

Example of a visitation during the "Geodiversity in Education" project

Source: the authors (2024).

In addition to the exhibitions, the project developed various didactic materials, such as booklets and educational kits, which functioned as portable mini-laboratories for teaching topics such as mineralogy, the rock cycle, and paleontology. Videos and texts were also produced, all made available on a

dedicated website. The activities presented geoscience content to the community, especially to elementary, secondary, and higher education students, and annually received an average of two thousand visitors interested in geosciences, geotourism, geoconservation, and non-formal education.

Considering the project's actions, the importance of university extension is highlighted. According to Freire (2021), it is necessary to build and execute extension actions in which the agents, the extensionists, are not treated as objects, but as transformative beings of reality. The author criticizes educational projects based on the simple transfer of knowledge, in which the extensionist assumes the central role and the public becomes merely spectators. Furthermore, this approach reinforces a mechanistic relationship, treating individuals as objects of persuasion rather than active subjects in the educational process.

The project stood out for adopting characteristics of non-formal education, offering a more flexible and dynamic environment that prioritizes interaction with visitors and provides a more attractive and free learning experience. According to Gohn (2020), non-formal education is a sociopolitical, cultural, and pedagogical process aimed at citizenship formation, preparing individuals to interact in society.

Thus, the results achieved by the “Geodiversity in Education” project, together with another extension project, called “Zoology in Focus”, from the Department of General Biology at UEPG, enabled the emergence of the MCN-UEPG.

Starting in 2019, the extension, research, and teaching project “UEPG Museum of Natural Sciences” inaugurated the museum's exhibition space in June 2022. The institution was the first of its kind in the Campos Gerais region of Paraná, Brazil, and has played important roles in heritage preservation, research, education, culture, scientific dissemination, and tourism. According to Pimentel, Mendes, and Liccardo (2022, p. 16), the MCN exhibits “materials obtained over more than 50 years of laboratory existence, enabling the sharing of a collection with high scientific value and didactic potential for studies of nature and its relationships with society.” The central themes of the exhibitions portray both the geological history of the Earth and the development of life in its ecosystems (Figure 2).

Figure 2

Example of a guided visitation at the MCN-UEPG

Source: the authors (2024).

The museum has a team composed of researchers, faculty, undergraduate and graduate students, and administrative staff. Among its educational actions, mediation stands out, providing the participation of undergraduate students from Geography and Biology programs. These students, both scholarship holders and volunteers, are responsible for welcoming visitors and communicating the exhibition content in a didactic manner, especially to the school groups that visit the MCN daily. Additionally, they are involved in research development and exhibition assembly.

The museum's geodiversity and biodiversity collection benefits from the collaboration of other didactic and research laboratories linked to the Geography and Biology programs. Moreover, the MCN maintains ties with postgraduate research in Geography, expanding its educational purposes.

Due to the multiplicity of actions involving undergraduates, there arose a demand for reflections on the contributions of the “Geodiversity in Education” (2011-2019) and “UEPG Museum of Natural Sciences” (2020-2025) projects to the education of these students. In this research, an analysis was conducted regarding the degree of scientific literacy fostered over the 14 years of project operation, in relation to the periods of participation of each member.

SCIENTIFIC LITERACY IN A SCIENCE MUSEUM

The concept of scientific literacy emerged in the United States in the 1950s. The American researcher Paul Hurd (1998) claims to have been the first to use the term as a goal for science education, in 1958. Furthermore, Hurd traces the history

of philosophical, social, political, and educational discussions that contributed to the formulation of this concept (Silva & Sasseron, 2021).

Currently, it is considered essential to educate citizens with a critical view of reality and active participation in society. In this context, scientific literacy can be highly relevant, as it has the potential to encourage the general public to use scientific concepts and language to understand the world, recognize the various scientific applications in everyday life, and act with greater awareness and responsibility (Costa & Lorenzetti, 2020; Krupczak, Lorenzetti & Aires, 2020).

However, one of the greatest challenges in studying scientific literacy is precisely its definition. Despite extensive discussion of the term in science education literature, there is still no clear consensus (Sasseron & Carvalho, 2008). Studies by Sasseron and Carvalho (2008, 2011) on scientific literacy in Brazil sought to discuss, based on relevant research, the concept and objectives of this proposition. One of the works highlighted by the authors is that of Laugksch (2000), who conducted a survey of literature published in English on the concept of scientific literacy, organizing different perspectives, descriptions, and interpretations in a comprehensive conceptual review. The authors report that Laugksch sought to align different ideas about scientific literacy, aiming to refine the concept. The analysis of the survey allowed the identification of common elements among the various definitions, which highlighted certain fundamental criteria for considering someone scientifically literate. Despite other possible frameworks, the definitions of science literacy cand scientific enculturation were considered encompassed in the concept of scientific literacy adopted in this investigation.

As a result of this analysis, the authors compiled arguments, organizing them into the Structuring Axes of Scientific Literacy, which seek to synthesize the skills identified by various researchers dedicated to the practice of scientific literacy. The axes dialogue with the idea of multidimensionality, as they represent different aspects addressed by scholars in the field (Sasseron & Carvalho, 2008, 2011).

The Structuring Axes of Scientific Literacy by Sasseron and Carvalho (2008, 2011) highlight different aspects considered essential for scientific understanding. The first axis addresses the basic understanding of fundamental scientific terms, knowledge, and concepts, which the authors consider indispensable for interpreting information and approaching everyday situations. The second axis concerns the understanding of the nature of science and the ethical and political factors that permeate its practice, emphasizing that decisions based on scientific concepts must be accompanied by contextual considerations. Finally, the third axis focuses on the relationships between science, technology, society, and the environment, recognizing the influence of science and technology on daily life and their relevance for building a sustainable future.

In a more recent publication, Silva and Sasseron (2021) highlighted the importance of revisiting the Axes they indicated in 2008 and 2011, proposing a reinterpretation based on considerations about science teaching as a social practice. The authors refer to the work of Roberts (2011) and Valladares (2021), in which researchers present and characterize the conceptions of scientific literacy found in the science education literature.

In this sense, Roberts (2011) identifies two predominant perspectives in science education curricula. “Vision I,” or internalist vision, focuses on the internal aspects of science, emphasizing the understanding of scientific processes and conceptual development. “Vision II,” or externalist vision, prioritizes the interactions between science and society, considering science as a social activity and highlighting its relevance for everyday decision-making. According to the author, the main distinction between these visions lies in their formative objectives, which influence both the choice of content and the didactic approaches in teaching.

More recently, Valladares (2021) analyzed the main approaches to scientific literacy over the past 20 years and explored the historical context of the visions organized by Roberts (2011). The author points out that Visions I and II of scientific literacy stem from advances in Science, Technology, and Society (STS) studies, which deepened discussions about the impacts of scientific and technological activities on society and made perspectives on the topic more complex. For Valladares, Vision I reflects a positivist perspective, in which science is seen as separate from society, while Vision II adopts a post-positivist approach, linking science to social issues. Furthermore, the author expands the discussion by proposing a “Vision III”, which emphasizes the need for active engagement in scientific and socio-scientific debates, including an explicit commitment to values such as equity and social justice.

Following these premises, Silva and Sasseron (2021) point out the current relevance of conceiving scientific literacy as a social practice that favors sociopolitical engagement. This perspective aims to encourage the active participation of the population in public debate about science, as well as the pursuit of fair, equitable, and common-good-oriented solutions to socio-scientific issues. Moreover, according to the authors:

> scientific literacy is only realized through the intense and delicate simultaneities and interferences between the approach to concepts, modes of knowledge construction, and forms of positioning and action in situations of life in society, through and from characteristics of the scientific activity. (Silva & Sasseron, 2021, p. 07).

While addressing the topic of scientific literacy, Lorenzetti (2021) stated that the term does not imply acquiring detailed and specialized knowledge but rather building a knowledge base that situates citizens within the context of scientific influences in their daily lives. Thus, scientific literacy involves understanding meanings and structuring a process of interpreting reality and social integration that enables individuals to identify, discuss, and apply fundamental concepts related to science in their lives. Therefore, a scientifically literate population is one capable of making choices based on scientific information about important issues such as health, environment, and technology, directly impacting society (Lorenzetti, 2023).

This debate demonstrates that scientific literacy goes beyond mastery of technical and scientific concepts, extending to the understanding of scientific processes, analysis of interactions between science, technology, and society, and the ability to make informed, evidence-based decisions. In a world increasingly influenced by technological advances and scientific challenges, promoting scientific literacy enables citizens to discuss complex issues and strengthens the

connection between science and citizenship, which can contribute to a more critical and conscious society.

In this context, the school assumes a relevant role as a privileged space for discussing the importance of scientific and technological knowledge and its influence on society (Lorenzetti, 2023). When teaching addresses topics present in students' communities, learning transcends the classroom walls, encouraging students to use scientific information in various everyday situations and gradually improving their awareness about the importance of science.

Even while corroborating the idea of the school's relevant role in the process of scientific literacy, it is important to emphasize that it should not be restricted to the formal school environment and that it can be promoted in different educational spaces. With this in mind, it is worth considering exhibition spaces such as museums and similar institutions, laboratories, botanical gardens, parks, internet pages, among others, which offer opportunities for transmitting scientific concepts in less conventional ways. Therefore, it is important to discuss different possibilities for developing scientific literacy, including varied spaces, approaches, and objectives.

According to Antonichen and Freire (2023), non-formal spaces such as museums and science centers can significantly contribute to scientific literacy. Activities associated with scientific literacy in these environments can awaken participants' interest in science in a dynamic way, providing them with the opportunity to interpret and relate to their own world and to explore knowledge in different ways (Pereira *et al*., 2021).

Science museums, the focus of this research, have specific characteristics. In general, they feature long-term exhibitions, which may include interactive modules, dioramas, planetarium sessions, living and non-living collections, as well as items of scientific and historical value, panels, films, and a variety of multimedia, multimodal, and sensory information. In the 1960s and 1970s, museums and science centers in Brazil began to offer temporary, itinerant, in-person and/or virtual exhibitions, as well as workshops and theatrical presentations, among other activities (Norberto Rocha & Abreu, 2021).

Another aspect that highlights the specificity of museums is pointed out by Schuindt, Silveira, and Lorenzetti (2018), who emphasize that science museums are considered environments conducive to social interaction between visitors and professionals working there, something that should not overshadow the educational process, but rather complement it. It is the responsibility of mediators to establish dialogues and discussions that ensure the connection between the museum exhibition and the scientific reality underlying each item or concept presented. This is because spaces that promote interactive activities with the public and aim to offer learning experiences that contribute to effective scientific literacy must be especially attentive to the clarity of their information.

In the context of the MCN-UEPG, this research focuses on those who make the museum possible: museum educators, mediators, and researchers. The survey of the contributions of scientific literacy for these groups can help strengthen the role of museums as spaces for scientific literacy and the development of educational programs that consider the training of mediators as a process of scientific literacy.

SCIENTIFIC LITERACY OF PARTICIPANTS IN THE "GEODIVERSITY IN EDUCATION" AND "UEPG MUSEUM OF NATURAL SCIENCES" PROJECTS

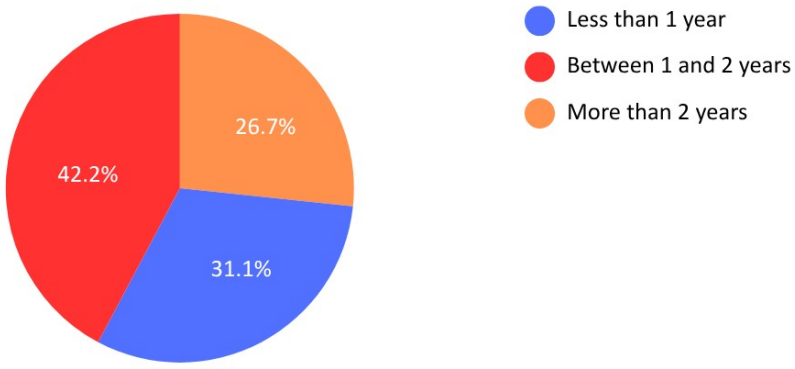
RESEARCH SUBJECTS

Since 2011, with the "Geodiversity in Education" project, through 2020 with the "UEPG Museum of Natural Sciences" project, and 2022 with the start of MCN activities, many extension students and researchers have acted as volunteer and scholarship collaborators in actions of these two projects. It is estimated that, among scholarship holders, volunteers, and professionals, more than 120 people participated in different work fronts, with durations ranging from one month to more than two years. Until 2019, only students from the teaching degree and, to a lesser extent, the Geography bachelor's program participated in the project; MCN activities now involve students from the Geography teaching degree, Biological Sciences teaching and bachelor's programs, Computer Engineering, and Tourism bachelor's program.

Despite all these variations, the study sought to identify the possible contribution of the projects to the scientific literacy of this group. Through a questionnaire with semi-open questions, each research collaborator expressed their own understanding of this process. The questionnaire was sent to about 90 subjects, of whom 45 responded. Of this group, regarding the time spent on the projects, 19 students were involved for a period of one to two years, 14 participated for less than a year, and the other 12 participated for more than two years (Figure 3).

Figure 3

Participants' time spent on projects



Source: the authors (2025).

Among the participants, 10 worked exclusively in the "Geodiversity in Education" project, 26 worked (and some still work) in the "UEPG Museum of Natural Sciences" project (including the museum setup period), and 9 participated in both. The comparison between the two projects is relevant, as the experiences in these two exhibition spaces present distinct characteristics and, in some cases, different audiences. The MCN, as an environment open to multiple fields of study, provides a more varied scientific experience, while the "Geodiversity in Education"

project offered training with an emphasis on geodiversity aspects, specifically aimed at Geography students.

Regarding the form of participation in activities, the data show a predominance of 25 participants acting as volunteers, followed by 17 extension scholarship holders, 11 scientific initiation scholarship holders, and 3 scholarship holders from the "University Without Borders" incentive program. The main roles performed by the students were research, exhibition assembly, and extension (direct interaction with the general and school community), through mediation of the exhibited collection and practical activities and workshops. However, some participants highlighted that they developed their research in the museum at various levels, including monographs, dissertations, theses, and mandatory internships.

Of the participants in this research, 24 students come from the Geography teaching degree, 9 from the Biological Sciences teaching degree, 4 from the Biological Sciences bachelor's program, 2 from the Tourism bachelor's program, 1 from the Geography bachelor's program, and 1 from Computer Engineering. Also responding to the questionnaire were 1 researcher with a degree in Visual Arts and 3 research/extension scholarship holders who participated in research and curatorial activities, with backgrounds in Informatics, Archaeology, and Physics. However, these professionals did not participate in mediation activities, which are among the main actions of the projects. Thus, the perceptions of these participants were not included in the following discussions.

On the other hand, the remaining students, who participated in a range of activities, such as mediation, workshops, exhibition assembly, research, and direct interaction with the public, had greater contact with the exhibitions and visitors. This closer involvement motivated the selection of these responses for analysis of the impact of their participation in the projects (especially in exhibition spaces) on the promotion of their own scientific literacy.

Regarding the type of participation in the projects, the data show that 31 subjects were scholarship holders, followed by 25 volunteers, revealing that scholarship holders were more numerous, albeit by a small margin. It is necessary to clarify that some students, even after their scholarships ended, continued to act voluntarily in extension and/or research development, which explains why the number of responses to this question is higher than the number of research collaborators.

Voluntary participation reveals the importance students attribute to these spaces (exhibition and museum) in their academic and professional training. The projects' actions provide a range of learning opportunities, as contact with the public and scientific exhibitions stimulates the development of academic and professional skills, considering that most students are in teaching programs. Furthermore, this prolonged period can be considered relevant for research development, which emphasizes skills in observation, data collection, and analysis.

The main roles performed by the students were research, exhibition assembly, and direct interaction with the school and general community, through mediation related to the exhibited collection and practical activities and workshops. It is necessary to reiterate that the analysis considered only the questionnaires answered by students/researchers who acted as mediators in the projects; thus,

the following data and information are based on only 41 of the 45 questionnaires answered.

THE SCIENTIFIC LITERACY PROCESS OF THE MEDIATOR GROUP

For the interpretation of information and data, considering the stages of the Content Analysis methodology (Bardin, 2020) and the choice of an exploratory study supported by theories in the field, the Structuring Axes of Scientific Literacy (Sasseron & Carvalho, 2008, 2011) were adopted as *a priori* categories of analysis.

Although new perspectives on scientific literacy have been brought by Silva and Sasseron (2021), the choice of the aforementioned axes is justified by their clarity and comprehensiveness, which provided an approach capable of guiding the analysis on the development of scientific literacy with a group that presented distinct backgrounds and differences in the duration of participation in each project. The choice of the units of analysis "theme" and "context" was guided by the intention of giving voice to the subjects, as well as by the objective of the questions presented to them. The process of analysis and interpretation of the accounts provided by the group enabled categorization into the following axes.

First axis: basic understanding of terms, knowledge, and fundamental scientific concepts

According to Sasseron and Carvalho (2011), the basic understanding of terms, concepts, and scientific knowledge is one of the pillars of scientific literacy studies. This axis addresses work with key scientific concepts used in various everyday situations and involves the assimilation of terminology, knowledge, and scientific principles. Thus, this dimension of scientific literacy is related to the acquisition of basic scientific language, but sufficient for individuals to recognize science as a useful and present tool in their lives.

The goal is for the person to acquire and internalize elementary knowledge to solve issues and approach everyday situations. Furthermore, grasping the fundamentals of science is important for social interaction, as well as for understanding information and data (Sasseron & Carvalho, 2011). By highlighting this axis, the aim is to identify evidence of conceptual and contextualized learning in the formation of the subjects of this research.

Therefore, this axis, as a category of analysis, seeks to identify in the participants' statements evidence of the assimilation of scientific knowledge from their involvement in the projects (exhibition and museum). Additionally, this axis allows observation of how concepts, terminology, and scientific principles are understood and applied in daily life, as well as the appropriation of knowledge that facilitates the interpretation of information and data. However, the research conducted was exploratory, seeking to recognize general aspects that could provide evidence for in-depth investigation. When asked about the contributions of the period to their knowledge and academic development, some participants highlighted:

> Through the collection available at the museum, it was possible to understand in practice many subjects related to natural sciences/geosciences, which we often only saw in theory, and from the time I spent there, I became more interested in topics in this field. (Geo.

> Teaching Student 43 - To maintain the confidentiality of participants' identities, only the course and the number assigned to each questionnaire answered will be indicated)
>
> By researching and handling the materials, it was possible to discover various information that contributed to building knowledge in natural sciences. Furthermore, by learning more about geodiversity, my interest in natural spaces and environments for biogeodiversity preservation increased. (Geo. Teaching Student 11)
>
> My ability to understand and interpret scientific information improved greatly, as the environment provided practical, interactive, and educational experiences that facilitated my learning. (Geo. Teaching Student 20)

The excerpts highlighted reveal that the participants' experiences contributed to their knowledge of scientific concepts related to the projects and museum themes and to developing skills such as interpreting information and applying knowledge. These accounts show that the activities carried out were significant, making science accessible and understandable, even in a non-formal learning environment, in this case promoting greater interest in natural sciences topics.

When asked about their level of interest and knowledge in natural sciences before participating in the projects and museum, all participants indicated some degree of interest. Regarding their prior level of knowledge in natural sciences, 22 participants reported having a low level of scientific knowledge in the area, 16 reported a medium level, and another 6 revealed a high level, mainly because they were completing an undergraduate degree, a second degree, or a postgraduate program. Additionally, all participants noted an improvement in their understanding and interest in natural sciences. The following excerpts reveal aspects highlighted by participants about their learning:

> The museum provided both greater interest and better understanding of local natural characteristics and processes, largely due to the daily experiences at the MCN and the constant revisiting of the themes presented in the exhibition. (Bio. Bachelor Student 08).
>
> Learning is continuous. Participating in museum activities broadened my knowledge in various fields. I have always been interested in Paleontology, and living with people who work in the area was important to expand my knowledge. (Bio. Bachelor Student 30).
>
> Without a doubt, the project helped me understand, in a scientific and didactic way, several topics I have always been passionate about, such as Geology, Biodiversity, Astronomy, and even Archaeology. (Geo. Teaching Student 40).
>
> Frequent contact with the collection and monitoring helped me gain a deep understanding of geodiversity topics and their importance to society, which I previously only had a basic notion of. (Geo. Teaching Student 07).

The above accounts show that, although participants had some initial degree of interest, their understanding of these topics was limited. Through participation in the projects/museum, they had direct contact with the collection, practical activities, and mediation, which allowed for a greater understanding of scientific content and its application, resulting in the improvement they reported. Their actions required research and interaction with the public, experiences that helped make concepts clearer and more meaningful for the mediators.

> The experience at the museum awakened my interest in natural sciences, which I considered distant from my daily life. This experience also made me realize the importance of science in preserving natural resources, something I did not see so clearly before. For example, in the workshops, I felt that my role went beyond teaching; I was also learning about the importance of these topics for society. (Geo. Teaching Student 29).
>
> I always had some interest in science, but it was only by participating in museum activities that I understood these areas more deeply. This increased my interest and changed my

> understanding of how science can be used to solve everyday problems, such as environmental and sustainability issues. These experiences showed me that science is not something distant, as it is all around us and is fundamental to society. (Bio. Teaching Student 27).

These statements reveal that the experiences lived by the participants awakened in them a greater interest in scientific topics, especially in natural sciences and geosciences, and promoted awareness of the importance of this knowledge for society. It was also observed that the interest in exploring and understanding the scientific world was reinforced by the activities developed and that the participants' understanding of topics such as geodiversity and biodiversity was broadened.

In excerpts reflecting this experience, participants reported developing a deeper understanding of scientific topics previously unknown to them and an improvement in their ability to share this knowledge with varied audiences. These experiences allowed participants to approach science as something applicable and relevant to everyday life.

The data show the presence of a scientific literacy process guided by the first axis, as participants demonstrate the appropriation of scientific content and the ability to recognize it as useful for understanding and interacting with the world. According to Sasseron and Carvalho (2011), it is necessary to understand scientific knowledge in a way that allows it to be applied in various everyday situations. The fact that students associate scientific knowledge with problem-solving or understanding everyday phenomena is a strong indication of progress in this axis.

In summary, the analyzed data indicate that the development of understanding of scientific terms, concepts, and content was significant for the participants. This construction occurred through educational practices in non-formal spaces, interaction with the public, and the need to master the topics to perform their roles in the projects. According to Sasseron and Carvalho (2011), this understanding is important because it allows the individual to interpret information more autonomously and to appropriate science as a tool for reading reality.

Second axis: understanding the nature of science and the ethical and political factors surrounding its practice

According to Sasseron and Carvalho (2011), understanding the nature of science involves recognizing that the production of scientific knowledge is a human, collective, dynamic, and historically situated process. This axis refers to the conception of science as a body of knowledge in constant evolution, through a process of data collection, analysis, and interpretation, which culminates in the construction of knowledge. Furthermore, it provides support for the inclusion of the human and social character inherent to scientific investigations (Sasseron & Carvalho, 2011).

Thus, this axis, as a category of analysis, aims to identify how participants perceive and reflect on the nature of science as a constantly evolving process, with emphasis on practices of data collection, analysis, and interpretation. Additionally, it seeks to understand how they recognize the human and social aspects in their scientific practices and how these elements influence their construction of

knowledge. The analysis focuses on the ethical and political relationships that permeate scientific work and how these issues are addressed or reflected in the extension, teaching, and research activities carried out within the projects (exhibition and museum). The following answers illustrate some of these perceptions:

> At the museum, I was challenged to analyze data and the implications they may have for society. I also began to consider how science impacts human and environmental well-being. (Bio. Bachelor Student 08).
>
> The scientific practice I experienced at the museum taught me the importance of respecting cultures and the environment. Now I realize that science needs to be done to benefit society as a whole, without harming nature. (Geo. Teaching Student 16).
>
> The project allowed me to conduct my first scientific research, which gave me a deeper understanding of scientific language, improving my interpretation and understanding of the processes of scientific construction. (Bio. Teaching Student 34).
>
> During my time at the museum, I was exposed to science all the time. I feel that my mind was thinking, reflecting, and articulating references scientifically. I formulated hypotheses, asked questions, and questioned things very easily. (Geo. Teaching Student 35).
>
> By conducting research at the museum, I began to realize that science is not just data, but a product of human interactions. Every new discovery has a context and understanding this changed my view of scientific research. (Bio. Teaching Student 18).

The excerpts highlighted reveal the participants' understanding of the human character of science, pointing to their interaction with scientific practice and experiences in research environments. The statements also reflect ethical and social values in the investigative process, emphasizing the social implications of science and the importance of awareness of the role of science for society and the environment.

Therefore, the accounts presented indicate that participants came to understand science as a human practice, constructed through investigation, hypothesis formulation, and data analysis and interpretation. This understanding relates to the second axis, as it involves the perception that science is embedded in historical and social contexts and that its results are not definitive. This change in perspective helps individuals consider different contexts whenever they encounter new information and circumstances (Sasseron & Carvalho, 2011).

When asked about the activities they developed during their time in the projects (exhibition and museum), mediation (also called monitoring, guided visits, and reception by participants) was mentioned by 28 participants, exhibition organization and assembly by 22, research development by 15, production of materials such as replicas and other didactic materials by 11, and participation and organization of events had 9 answers. The following excerpts reveal some remarkable experiences:

> [...] the monitoring itself, because every day there was a different audience, so we had to adapt the language of explanation and give diversified examples. This way, we had a broader view of the subjects we explained during monitoring. (Geo. Teaching Student 03).
>
> We managed to take the project to various events. The most impactful was presenting our project 'Geodiversity in Education' in Portugal at a Geosciences Congress at the University of Coimbra. (Geo. Teaching Student 19).
>
> "The opportunity to participate in a geology event was a milestone in the years I participated in the project. We had access to a large scientific event, could present our work, meet professionals, visit museums and various places of geoscientific importance

> that we had previously studied. And, as teacher training, monitoring groups in the museum was impactful for the development of my didactic and communication skills. (Geo. Teaching Student 21).

Participation in congresses, both local and international, and the organization of workshops during "Museum Week" were highlighted by participants as moments of learning. These activities, in addition to strengthening the students' scientific foundations, helped expand their understanding of the role of museums and extension projects in communicating science to the community.

Among the actions mentioned, mediation was one of the most impactful activities for students. According to them, research experiences and interaction with varied audiences promoted the development of their communication skills and led them to reflect on their posture and speech. Furthermore, the activities provided participants with a better understanding of scientific content. Here, the recognition of mediation as a teacher training process and the appreciation of the museum's educational role stand out. The following excerpts reveal some perceptions of participants regarding this relationship with teaching:

> When a school visited the museum and, within that group, a specific student showed interest in paleontology and wanted to become a paleontologist, after talking a bit with the boy, I could see how much interest and passion he had for the field and ended up encouraging him to pursue it. It was an impactful moment, where I realized that the path of education was present in my life, through the contact with schools visiting the museum. (Bio. Teaching Student 27).

> I believe that planning and executing workshops during the 'Museum Week' event was very productive, as I worked with many students of different ages. Creating activities aimed at children in non-formal education is a challenge that provides growth in the teaching field. (Geo. Teaching Student 29).

> As a teacher, [the activities] helped me understand the profession, as well as think about mediation that could be proposed in the classroom. Thus, the project provided me with a series of pedagogical mediations that currently help me in class. It was also very valuable for research, since it was my first PIBIC. This process, in addition to research, matured me and gave me experience to pursue a master's and doctorate in the future. (Geo. Teaching Student 06).

The mediation, workshops, and event organization actions highlighted by participants contributed to their experience of the scientific process in different situations and spaces. By interacting with varied audiences and communicating scientific content to museum visitors, participants were led to reflect on the language, limits, and purposes of science. Moreover, they considered the human and social character inherent to scientific investigations, characteristics present in the second axis proposed by Sasseron and Carvalho (2011).

In addition to mediation, activities such as exhibition assembly and the development of didactic materials were also important in the training of these students. The production of materials, such as the documentary on South American geodiversity or the assembly of replicas, promoted a more concrete understanding of the themes, while the organization and participation in events broadened participants' views on science.

Another aspect highlighted by participants was the learning gained from interactions with faculty and researchers. In response to the question "Did you have the opportunity to interact with faculty and researchers from UEPG or other institutions? If so, did these interactions influence your understanding and interest in science? How?", 42 participants reported having contact with faculty and

researchers and that this contact contributed in some way to their scientific literacy. The following excerpts reveal some perceptions regarding these interactions:

> [...] with several researchers, both from UEPG and other institutions. They influenced the expansion of scientific knowledge and the discovery of new perspectives and approaches. (Geo. Teaching Student 02).
>
> These faculty and researchers – especially in areas different from mine, such as Biology and Archaeology – helped me have a broader view of science itself, because I realized that its different fields do not exclude each other, but instead add up for a better understanding of the whole. (Geo. Bachelor Student 04).
>
> I had the opportunity to interact with various researchers, professors, and students from different locations in PR, Brazil, and the world. This happened through events, technical visits, and lectures held within the two projects. These exchanges definitely influenced my motivation and interest in the subject. (Bio. Teaching Student 33).
>
> [...] this exchange of knowledge helped me realize how different disciplines complement each other. It was an experience that broadened my view of scientific construction; I realized that science is not done in isolation, but through the collaboration of different fields of knowledge. (Geo. Teaching Student 11)

By encountering researchers from various fields, such as Biology, Geography, Geology, Paleontology, and Archaeology, participants had the opportunity to perceive the different areas of science in an integrated way and understand how all disciplines relate to the understanding of natural and social phenomena. This contact provided them with an interdisciplinary vision, and the statements reflect how these interactions, by exposing participants to new perspectives and knowledge, helped deepen their interest in natural sciences and geosciences.

The dedication of the faculty and researchers involved in the projects also inspired the students. Many participants reported that this experience reinforced their desire to pursue a scientific career and influenced their choice of academic paths. Furthermore, living with experienced researchers showed them that knowledge is constantly being constructed and encouraged them to seek continuous learning and adopt a more questioning and critical attitude toward their daily lives. The following excerpts highlight these aspects:

> Observing the dedication of teachers and researchers at the museum awakens the interest to get more involved in the projects, influences the perspective as future teachers, so that they do not get discouraged along the way, noting the role that education and teachers have in society. (Geo. Teaching Student 31).
>
> Many of the other monitors were researchers; in addition, other members of the museum project were university professors. The other monitors helped me better understand how academic research is done. (Bio. Teaching Student 07).
>
> I had contact with professionals from various institutions and different fields. These interactions complemented my learning and always showed that my knowledge was still very limited, since we had access to very experienced professionals. I consider this characteristic essential for students to keep studying and not settle for what they find in their own course. (Bio. Bachelor Student 36).
>
> At the museum, I lived with researchers from different fields, which made me understand that science is a construction that involves various disciplines; this is essential for understanding reality. (Geo. Teaching Student 16).

Within the context of the projects (exhibition and museum), participants had direct contact with research and mediation activities, as well as involvement in events and exhibitions. These processes instilled in them the notion that science is

not a fixed field of knowledge, but something dynamic and constantly evolving. Interaction with teachers and researchers from different fields also allowed participants to understand the importance of collective processes in knowledge construction, as well as to visualize the diversity of perspectives and approaches that make up scientific practice.

In summary, the data analyzed in this section indicate that the second axis of scientific literacy was mobilized. Participation in research, mediation, and exchanges with other professionals enabled participants to develop a broader understanding of science as a process. The subjects came to recognize the provisional and contextual nature of scientific knowledge and to reflect on the social and ethical implications of scientific actions. This training process is in accordance with the principles of Sasseron and Carvalho (2011), who emphasize the importance of understanding science as a human construction embedded in cultural, political, and social realities.

Third axis: understanding the relationships between science, technology, society, and the environment

According to Sasseron and Carvalho (2011), the third axis of scientific literacy is related to understanding the interrelationships between science, technology, society, and the environment. Recognizing these connections enables individuals to critically analyze the impacts of science on daily life and to position themselves regarding social and environmental issues, reflecting on their actions and choices. Therefore, this axis addresses the understanding and application of knowledge produced by science in favor of a sustainable society.

In the process of identifying the interconnection between these spheres, it is important to consider that an immediate solution to a problem in one area may later result in the emergence of another problem. Thus, the importance of a deeper understanding of the applications of scientific knowledge and awareness of the consequences of its misuse must be emphasized.

Therefore, this axis, as a category of analysis, seeks to identify how participants understand and apply scientific knowledge to promote a more sustainable society, and how they recognize the relationships between science, technology, society, and the environment.

The analysis focuses on how the practices and experiences lived in the projects' activities influenced the understanding of the impacts of scientific actions, as well as exploring the problems and solutions that arise from the application of this knowledge in the socio-environmental context. The following statements reveal the participants' opinions regarding the relationships between science, society, and the environment, and how the experiences in the projects contributed to their understanding of sustainability and the impacts of science on reality:

> During guided visits, I realized how local geodiversity directly influences the region's biodiversity. This relationship between the two, something I had never stopped to reflect on, made me understand the importance of preserving both to ensure sustainability. (Geo. Teaching Student 12).
>
> Discussions with colleagues from different fields, such as biology and geography, made me understand that science cannot be seen in isolation. Each discipline contributes to social

> and environmental aspects, and all are important for improving society and conserving the environment. (Tourism Bachelor Student 01).
>
> I realized the importance that geodiversity and biodiversity have in society, and that they are essential to be addressed in schools and discussed in society, especially regarding environmental issues. (Geo. Teaching Student 42).
>
> I had the opportunity to interact with colleagues and professors from biology and geography and from different courses that visited the museum last semester. These interactions taught me a lot about different ways of looking at science, both from a sociological point of view and regarding scientific knowledge itself. (Geo. Teaching Student 06).
>
> By participating in a project about geodiversity, I realized that we are raising awareness about the need to preserve natural resources for ourselves and for the future. (Geo. Teaching Student 38).

These excerpts demonstrate the participants' awareness about the importance of geodiversity, biodiversity, and environmental preservation, reinforcing the interdependence between these elements and the responsibility of science in seeking solutions that meet current needs without worsening future problems. In this sense, it is clear that the experiences in the projects stimulated reflections on the role of science in building a sustainable future.

Therefore, these perceptions reveal that participants were able to recognize how scientific knowledge is directly related to environmental and social issues experienced in their surroundings. Thus, there was progress in developing the third axis, as described by Sasseron and Carvalho (2011), as participants demonstrated the development of a critical understanding of the applications of science. When they articulate elements of geodiversity, biodiversity, and environmental preservation, they highlight that they have come to understand science as part of social and environmental dynamics and that its use can directly impact natural environments and society.

When asked about the development of their own ability to reflect on current issues and think critically during their time in the projects, 39 participants reported an increase in their ability to interpret and understand scientific concepts throughout their involvement. According to them, frequent interaction with the collection and mediation practices allowed for a better understanding of various scientific topics, which began to be addressed in a contextualized manner. The following statements reveal these perceptions:

> The greater the scientific foundation, the better our understanding. This was possible thanks to: a) the depth of the topics, necessary for developing research projects, b) the need to make the content didactic for extension activities, and c) the direct contact with materials and study sites, such as laboratory samples and field research, which brought theory into reality and showed the real complexity of the natural sciences. (Geo. Teaching Student 37).
>
> My ability to reflect on current issues and think critically was improved during my work at the natural sciences museum. The museum environment requires me to update and interpret new scientific information, while interaction with the public and collaboration with a multidisciplinary team force me to consider different perspectives and apply scientific concepts to real contexts. These experiences have been fundamental for the development of my critical thinking and reflection on current issues. (Tourism Bachelor Student 01).
>
> The experiences we acquire at the museum enrich our critical sense, allowing us to see and analyze various situations differently. (Geo. Teaching Student 15).

> Exposure to scientific concepts in an accessible way helped develop critical thinking skills and connect theories with practical applications in the real world. (Tourism Bachelor Student 23).

According to the participants, their research experiences were another aspect that contributed to the development of their interpretation and scientific reasoning skills. Through study, publication writing, and events, participants had the opportunity to use scientific language in practical contexts and exercise critical thinking. Living in a scientific environment allowed them to formulate questions, raise hypotheses, and reflect on different scientific topics. Additionally, some reported that, through interaction with the public and living with the team, they began to consider topics of social impact. The following statements reveal these perceptions:

> Critical thinking was mainly developed through research. To conduct research, it is necessary to critically observe current issues and past issues (which certainly impact the present). (Geo. Teaching Student 03).

> The research I participated in allowed me to think more critically about how it relates to reality. The need to ask questions and create hypotheses was fundamental for my intellectual development. (Geo. Teaching Student 16).

> Publications and participation in scientific events helped me understand the importance of scientific language and better articulate my thoughts on social and environmental issues. (Bio. Teaching Student 27).

> During research and discussions, I was challenged to think critically about how discoveries can be applied, considering social and environmental impacts. (Geo. Teaching Student 19).

Sasseron and Carvalho (2011) emphasize that it is necessary to understand the applications of knowledge produced by science and how they can impact the environment and society. By articulating their experiences in the museum with issues such as sustainability, conservation, and environmental education, participants demonstrate the development of the ability to reflect on real problems and their scientific implications, which points to a process of scientific literacy.

These experiences influenced their professional perspectives and academic choices, leading some interviewees to opt for continued involvement in the scientific field, especially in areas related to education and the environment. In this regard, 25 participants responded that their time in the projects influenced their academic and professional paths. Below are some excerpts highlighting these perceptions about changes in their academic trajectories:

> My work at the museum influenced my decision to pursue a career in the natural sciences. The experience gave me a deeper understanding of the importance of scientific education and research, and inspired me to contribute to knowledge dissemination and environmental conservation. (Geo. Teaching Student 42).

> My time at the museum expanded my knowledge in physical geography, and thus, in the future, I can develop research and work related to the subjects exhibited at the museum. (Geo. Teaching Student 02).

> It was my first contact with research, and it brought me writing experience, contact with other researchers, exchanges of experiences, and a great reflective foundation. It opened doors for me to think about pedagogical practice and the possibility of making research a reality for academic progression. I am very grateful for the opportunity, as it made me realize that being a teacher was what I wanted and awakened my interest in scientific research. (Geo. Teaching Student 38).

Four participants, who changed their field of work, highlighted the contributions of the period regarding reflections, learning, and the social role they developed:

> I ended up not going into the geosciences field, but I really like it and still study geosciences and geoconservation in preservation environments. (Geo. Teaching Student 11).
>
> I already had a career established when I joined the museum; however, participating in museum projects broadened my interest in other areas. (Bio. Bachelor Student 30).
>
> I did not pursue a career in the geosciences field, but it was during the project/museum that I saw a social role in myself and felt important for the first time in my life. The university experience and the assignment of responsibilities brought me emotional benefits that changed my life for the better. (Geo. Teaching Student 35).
>
> Although I did not continue in the field, the project was the best path I could have found in my undergraduate studies. In it, I developed practical/applicable skills and knowledge to give back to the community and teach students, in addition to contributing greatly to my intellectual and cultural development. (Geo. Teaching Student 37).

Throughout their participation in the projects, the students developed a better understanding of the importance of science for society and realized the relevance of scientific education. This became more evident in the perceptions of those who chose to pursue graduate studies or teaching careers, spaces where they can continue to disseminate knowledge and promote scientific literacy in the community.

Among participants who chose other professional paths, the experience in the project/museum served to instigate a more critical understanding of science, as well as to strengthen skills such as communication and scientific thinking. Once again, the participants' accounts on the importance of preserving the environment and disseminating scientific knowledge reflect the development of a deeper interest in science.

Therefore, it is possible to affirm that the experiences lived by participants in the projects favored the development of the third axis of scientific literacy in their trajectories. Interactions with environmental topics, involvement in educational actions, and contact with the public broadened their perceptions of the role of science in society and the need to make responsible decisions in the face of contemporary challenges, fostering a more critical and conscious approach to scientific practice and its impacts on the world.

Based on the analyses and taking as reference the Structuring Axes identified by Sasseron and Carvalho (2008; 2011), it can be concluded that the period of student involvement in the projects played an important role in the development of their scientific literacy. Participation in activities, contact with the collection, and mediation enabled the group to understand scientific concepts, especially in the fields of natural sciences and geosciences, some of which had previously been seen only in theory.

By applying knowledge in diverse contexts, such as exhibitions, interactions with the public, or the production of materials, students were able to broaden their understanding of science and its application in everyday life. This process, favored by contact with the exhibited collection, allowed for the establishment of different connections with the environment and society. Such learning proved significant in stimulating the participants' interest and understanding of natural sciences, strengthening their scientific literacy.

The period of involvement also deepened the participants' understanding of scientific research and its procedures, allowing them to experience the human character of science. Experiences in data collection, hypothesis formulation, and participation in scientific events provided them with the understanding that science is a constantly evolving process that requires a permanent reflective attitude. Likewise, collaboration with researchers from different fields strengthened students' understanding of science as a collective and social endeavor.

It is also noteworthy that the period of involvement enabled participants to reflect on the relationships between science, technology, society, and the environment. The experiences they reported allowed them to understand how scientific knowledge is applied to solving environmental and social problems. Contact with topics such as geodiversity and biodiversity, interaction with different audiences, and immersion in a research and scientific education environment fostered the development of critical thinking among the subjects of this study and encouraged them to consider the consequences of human actions and the role of science in building a more sustainable future, particularly in the field of education. Some participants also reported that the experience influenced their academic and professional choices, highlighting the impact of scientific literacy on their trajectories. There was a consistent contribution to the formation of professionals and individuals became more aware and capable of reflecting and acting on issues involving science, society, and the environment.

FINAL CONSIDERATIONS

Scientific literacy, understood as the process of developing knowledge for understanding the role of science in society, has become increasingly necessary in light of current educational challenges. Therefore, promoting scientific literacy has become one of the main objectives in various teaching environments, such as schools, museums, and other spaces dedicated to scientific dissemination, development, and communication. It is thus relevant to conduct research that investigates actions promoted in these environments and their potential contributions and outcomes.

In this study, the personal perceptions of students who have participated or are still participating (as mediators and/or researchers) in the extension projects "Geodiversity in Education" and "UEPG Museum of Natural Sciences" regarding their scientific literacy were examined. Considering the three structuring axes proposed by Sasseron and Carvalho (2008, 2011), the data showed that the group experienced gains in the aspects analyzed. Overall, the data indicated a relatively balanced development among the three axes, although the experiences tended to favor the third axis in particular, with an emphasis on strengthening the relationships between science and society. The results demonstrated the breadth of scientific literacy promoted by exhibition spaces, which involved teaching, research, and extension in their activities.

This analysis was based on the perceptions of 45 higher education students who participated in the extension projects over the past 14 years, both developed on the UEPG campus, in the fields of geosciences and natural sciences, and which culminated in the creation of the MCN. Despite some particularities in the framing

of each structuring axis, this assessment allowed for a satisfactory understanding of the scientific literacy process that occurred in these spaces, even considering the different timeframes and actions experienced by the participants. Those involved in the research reported positive impacts on both their professional and personal lives, as well as gains in relevant knowledge, which applies even to those who moved away from geoscientific or teaching careers. It is worth noting that the statements explicitly reveal the participants' awareness of their own learning and its implications.

Participants reported deepening their knowledge related to geodiversity and biodiversity and their awareness of the role of science in addressing social and environmental issues. The data supported the idea that non-formal education spaces, such as science museums, by offering educational actions that seek to bring science and society closer together, play a significant role in promoting scientific literacy.

The understanding of basic scientific concepts, reflection on the nature of science and its social implications, and the perception of the relationships between science, society, and the environment proved to be relevant for the formation of a critical and reflective perspective among the participants, corroborating the process of scientific literacy.

This research adds to others that currently address museum education and scientific knowledge in the natural sciences, seeking to provide relevant theoretical and practical elements for the construction of a cultural educational project for the MCN-UEPG.

NOTES

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