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The participation of deaf and hard of hearing children in non-formal science activities

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Non-formal education is an important resource to foster scientific competence for active and responsible citizenship. However, these spaces do not always have the necessary requirements for everyone to access and participate. Therefore, with the intention of contributing to the creation of barrier-free spaces, the present study aims to identify the most appropriate psycho-pedagogical supports for the design and implementation of a scientific activity for a group of deaf and hard of hearing children. To achieve this objective, an instrumental case study was employed. The results, obtained through direct observation, satisfaction questionnaires, and interviews, show great interest among the children and both the sign interpreters accompanying the sessions and the organizers from the association assessed the activity in a positive light. These results also point to the need for spaces that could initially be controlled and that might strengthen the expectations among the participants and their families of participation in similar initiatives within more heterogeneous groups.

KEYWORDS

non-formal education, deaf and hard-of-hearing children, inclusive education, scientific inquiry, special educational needs

1. Introduction

Non-formal education is understood as the set of all those activities that complement and give continuity to formal education (Colom, 2005). Visits to museums or interpretation centers, participating in extracurricular sports and cultural activities, or attending artistic courses are examples of this educational modality. For Deaf and Hard of Hearing (hereinafter DHH) people these spaces can be an essential resource for access to scientific knowledge (Dias et al., 2014) in a playful and interactive way (Pita-Carmo and Massarani, 2022b). Specifically, Schoffstall et al. (2016) assert that extracurricular activities facilitate DHH children

> the chance to solve problems and overcome challenges; to develop skills in the social, academic, and physical domains; to belong to peer groups and establish positive and supportive mentoring networks; and to transfer the skills they acquire to a postsecondary setting (p. 189).

The absence of legal regulation or structure (Cabalé-Miranda and Rodríguez-Pérez de Agreda, 2017) offers greater methodological and organizational freedom than formal settings that provide a wide range of opportunities to create educational spaces that ensure access to information and active participation in the exhibitions, performances, and activities proposed. In this dynamic and flexible scenario, new approaches to teaching processes can therefore be introduced and tested, strengthening academic knowledge and the skills and attitudes that contribute to improving coexistence and respect for diversity.

Making the most of this reality, members of the Experimental Science Didactics area of the University of Burgos have been implementing the "*Science on Saturdays*" project since 2015, whose objectives are three-fold: (i) to encourage primary school children to approach science in a relaxed and stimulating way using two active methodologies: scientific inquiry and engineering design; (ii) to provide a space for pre-service teachers where their own didactic designs can be implemented and their teaching skills evaluated; and (iii) to invite institutional participation with the aim of creating a culture of inquiry that contributes to the improvement of science teaching-learning processes within schools (Greca et al., 2020).

The direct impact of the project on the people involved with the three above-mentioned objectives was very positive, demonstrating a high level of interest and involvement (Greca et al., 2020). However, a deeper analysis of the participants revealed an almost total absence of children with special educational needs, that is, those who require different educational supports than those usually provided in a specific context, even though the local press and the schools had shared details of the activity. Faced with a lack of diversity that hardly corresponded to the reality of most school classrooms in our area, three of the project leaders, who are also the authors of this study reflected on the objectives of the project and its commitment to the scientific-technological literacy of all children and decided to enter into direct contact with various local associations to directly promoted the activity with them. This initiative pursued a triple objective: (i) to awaken (and to strengthen) the interest of the children in science within familiar spaces where they felt safe; (ii) to establish relations with the association and their families and to discover any reasons for non-attendance at the workshops; and, finally, (iii) to ensure the support that each group needed, on the basis of the scientific evidence, in order to remove all barriers that might hinder participation in the workshops that were open to all children.

Specifically, this paper is focused on the experience developed with a group of children belonging to a DHH association, with the aim of identifying the psycho-pedagogical supports that guarantee their access to and participation in non-formal science activities.

To that end, the state of the art regarding the teaching-learning processes of DHH children at school is analyzed as a basis for the design of the didactic sequence implemented in the project.

2. Science education for DHH children

Research into science teaching and learning among DHH learners is scarce (Santana and Sofiato, 2018; Raven and Whitman, 2019). It is a limiting factor in the development of didactic approaches that go beyond science teaching based on vocabulary development, repetition, and teacher-centered methodologies (Hagevik et al., 2011) that prioritize the presentation of a topic and the subsequent performance of reading and writing activities (Vázquez, 2019).

The implementation of this approach to science teaching, which compromises the learning of DHH children, is also reinforced by limited resources and teacher training (McGinnis and Kahn, 2014) on inclusive education models and on DHH children educational needs. These facts lead to decisions such as setting educational objectives that force the teaching and learning of oral language as the primary, and exclusive, means of access to knowledge and participation. For years, these decisions backed by educational institutions have contributed to demotivation, low self-esteem, and school failure among DHH children. A lack of respect for the rights of deaf people that has been denounced for years by the deaf community not only in Spain but also in other countries. Their demands have led to progress on human rights issues thanks to the approval of a law that recognizes Spanish sign language as an official language. However, there are still situations of inequality that demand the promotion of fully accessible and inclusive environments, access to bilingual, equitable and inclusive education, the visibility of sign language, diversity, associative unity, and the culture of the deaf community (State Confederation of Deaf People; CNSE, 2021).

Despite these obstacles, the contributions published to date allow us to move toward educational models that are more respectful and efficient with students' needs. According to the literature review developed by Santana and Sofiato (2018) on science education and DHH learners, several studies show that active methodologies contribute to an increased interest in science learning, the development of autonomous learning, a better understanding of science content, and the strengthening of self-esteem and self-confidence. Prominent among these is the methodology of scientific inquiry, widely advocated in the scientific community as a suitable for science teaching and learning (European Commission, 2007), whose implementation has also yielded successful results with children with special educational needs and on inclusive groups (Lynch et al., 2007).

Inquiry-based learning process is characterized by the posing of questions concerning researchable problems of relevance to children, which are initially addressed based on their prior knowledge and experience. These questions lead to the formulation of hypotheses and the design of the experimental process, which allows scientific knowledge to be generated through observation, manipulation, argumentation, and dialogue (Couso et al., 2020). This methodology allows the generation of a variety of learning experiences that can be adjusted to the diversity of ways that children approach reality and learn, as recommended by the principles of Universal Design for Learning (hereinafter UDL) to ensure engagement in the learning process, access to knowledge, and active participation. But to succeed, it is essential to know the characteristics of the children involved: their interests, prior knowledge, and preferences for social and physical interaction (Duarte et al., 2016; Coll et al., 2020).

Additionally, when it comes to DDH children, it is necessary to ensure that it is used "a shared and effective communication system to establish interactions with their social environment and to access curricular content" (Domínguez, 2009, p. 52), either oral language or sign language. On the one hand, if the children use sign language a teacher knowledgeable of sign language will be needed in the process (Kurz et al., 2015). If the teacher does not know sign language, she/he has to be accompanied by an interpreter with whom he/she must establish close coordination (Dias et al., 2014). Agreeing in advance on the content and vocabulary to be used during the activities is required, since sometimes the interpreter may not know a specific sign or phenomenon that appears in the subject, especially in higher grades (Molena et al., 2017). Furthermore, it is also essential for DHH children to reason and argue the subject matter with other signers, which is why teachers with experience in working with DHH students request exclusive educational spaces where they can pass time together (Vázquez, 2019). On the other hand, if the child wears conventional hearing aids or implants and is an oral language user, technical and didactic strategies that favor oral perception must also be considered, since their use does not guarantee either access to information or participation. Some of these strategies are the use of FM equipment that prioritizes the reception of the wearer's message and minimizes background noise and the facilitation of lip-facial reading, which is often complementary to hearing.

To ensure an inclusive educational space, visual aids are of particular importance since DHH people have better developed visual rather than auditory skills (Lomber, 2017). Visual elements support the introduction of concepts and the explanations of the instructor, through images, keywords written on a blackboard, videos with subtitles in either written or sign language and graphic and pictographic diagrams, as well as the identification of relevant textual information through underlining and words written in bold.

Using the visual channel to communicate with the environment makes it necessary to take care of the arrangement of the children in the space to favor direct visual contact with all the participants. For this reason, a "U-shaped" arrangement and careful timing are recommended to address the likely problems arising from divided attention. Students with normal hearing can easily and simultaneously integrate verbal information from the exterior world (i.e., comments of a speaker) and information encoded within physical objects (i.e., images). However, this simultaneous integration becomes more challenging for DHH people. They need to look, in a sequential way, first at the person giving information and then at the physical world. When this strategy is not followed, DHH learners may easily miss messages and mental fatigue ensues (Marschark and Knoors, 2012).

3. Methodology

The study presented here is framed within a qualitative research paradigm with the aim of gaining a holistic understanding of a complex reality through experience of the subjects (Gil et al., 2017).

In particular, the nature of this research requires the use of an instrumental case study, as the aim is to understand and to analyze in depth and in a systematic way the teaching-learning process that takes place in a unique setting. It aims to strengthen existing knowledge and to open up new avenues of research (Stake, 1995) that will allow further progress toward inclusive educational models. The selected case is considered as a delimited system with an intricate relationship with political, social, historical, and above all personal contexts that need to be taken into consideration (Stake, 1995) such as their individual ways of communication.

3.1. Context (setting and participants)

The initiative brought together 15 children between the ages of 6 and 16 with an average age of 9,8: 9 DHH children and 6 hearing family members invited through the association of which they are members after being contacted by the project organizers. The activity was free of charge and voluntary so all families interested in participate were welcome. Prior to the design of the activity, the project leaders were warned of the age and characteristics variability of the group due to the limited number of people in the association, which is located in a small town.

The group of DHH participants reflects the great diversity within the deaf community. Spanish sign language was the mother tongue of two participants. One used conventional hearing aids with little hearing ability while the other wore two cochlear implants and displayed sufficient knowledge of oral code to cope with ordinary communication, although it was still low both for learning scientific language at school and for understanding texts.

Of the remaining seven people whose mother tongue was the oral language, one had sufficient knowledge of sign language to learn the curricular contents by these means; however, the child displayed medium-to-low oral language ability and low reading ability. The other six people had similar and even higher levels than the non-deaf people for both oral and written language, because of the constant stimulation they had received since early childhood. However, their knowledge of sign language was poor. In terms of technical aids to facilitate the hearing of this DHH group, two people had a bone anchored implant, two others had conventional hearing aids, while the remaining three used no aids.

3.2. Instruments

The integration of the perspectives of all actors in the case study becomes essential to preserve the reality comprehensively (Stake, 1995) through different instruments to collect evidence (Yin, 2009). For this reason, in this study, data were collected from all the participants, so that the strong and weak points of the design of the workshop and its implementation could be understood in a holistic way, through three instruments: direct observation by two of the researchers of this study; semi-structured interviews with the professionals from the DHH association who participated in the workshop; and a questionnaire for the participating children.

Prior to the workshop, six indicators were set out that researchers were expected to observe and record with descriptions and field note during implementation, because of their relevance when creating barrier-free learning and participative spaces for DHH learners. These indicators were: the organization of the space; respect for divided attention; the treatment of auditory and visual fatigue; the use of language and dialogical interactions between children and with the instructor; the use of visual aids; and implementing the process of scientific inquiry.

Once the workshop was over, a non-compulsory Likert-type questionnaire was distributed to the participants. The purpose and the content of the questionnaire as well as the questions were communicated orally by the instructor and in sign language by the interpreters. This instrument had four response options (Not at all; A little; Quite a lot; A lot), in which five questions were asked to be able to infer their degree of satisfaction: *Did you like the workshop? Did you like learning science by doing experiments? Did you like the way the workshop was conducted? Did you like the subject matter of the workshop? Would you like to learn science at school in this way?* In addition, the questionnaire included a multiple-choice question on the content of the workshop in which only one of the answers was correct: *In general, which soil do you think is better for planting?*

Finally, a semi-structured interview was conducted with three professionals from the association. The interview lasted 52 min and was audio recorded with the permission of the participants. Once completed, it was transcribed for further analysis and names encoded to guarantee the anonymity of the professionals interviewed (I1, I2, and I3).

During the interview, two of the study's authors raised questions focusing on three topics: the participation of the children of the association in non-formal education activities; the reality that DHH pupils face when learning; and the analysis of the successes and mistakes

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detected during the workshop. The authors analyzed these topics previously by a literature review and the field notes collected during the observation phase to be more precise and effective during the interview.

3.3. Procedure

The workshop lasted approximately 2 h and dealt with the study of three different types of soil: clayey, sandy, and loamy soils and their suitability for use as soil for cultivating plants.

The teaching methodology was guided scientific inquiry (following the classification of Martin-Hansen, 2002), in which the teacher defines the research question, as well as the process of experimentation. In addition, the role of the teacher is also focused on guiding the process, introducing and clarifying concepts and procedures, giving participants a voice and helping them to ask questions, to reflect upon and to argue about what they observe, the results, and the conclusions they draw.

The workshop was entitled "The soil speaks to us" and was divided into six steps: (1) contextualizing the workshop, (2) posing a research question, (3) communicating preliminary ideas, (4) experimenting, (5) collecting and analyzing data, and (6) drawing conclusions. Throughout the whole process, dialogue between peers, as well as with the teacher, assumed special relevance. Initially, participants were asked some questions to focus their attention on the topic to be discussed and to get to know their ideas, experiences, and previous knowledge. *What do you think we are going to do in the workshop? What do you think the soil can "tell" us? Why do you think we should consider what it "tells" us?* The research question was then formulated: *What characteristics does the soil need to have in order to favor plant growth?* During this discussion, key vocabulary was introduced and the whole group was encouraged to participate. Once the question had been raised, the workshop was organized around the study of three variables: (1) quantity of organic and inorganic matter, (2) permeability, and (3) consistency, in three different types of soil: (a) sandy, (b) clayey, and (c) silty-loam. The key vocabulary of the subject was also reinforced at this stage.

The group of 15 participants was divided into five subgroups. Their placement in the space was based on two criteria. Each subgroup consisted of three people in a triangle, so that when working in a group they could all see each other's faces and the materials they were handling. In addition, during the experimentation process, each member of the group oversaw a soil sample, so that they could sequentially compare the results obtained in the study of each soil variable. These subgroups were arranged in a "U" shape, so that the instructor and the materials presented could be easily seen. Moreover, two sign language interpreters joined the groups of children where the signers were.

Specific support of three different types was offered during the workshop to adjust the process to all children: personal, linguistic, and visual, to facilitate access to information, to promote their participation, and to enhance autonomy in their work.

- Personal support: The workshop was organized with three professional profiles: on the one hand, the instructor in charge of the workshop, a special education teacher with extensive experience in conducting scientific-technological workshops, but with no previous experience with DHH children. The instructor conducted the session using only oral language, as she was not familiar with sign language. There were also support staff for each subgroup, whose function was to regulate the activity, necessary at three points in time: when the children had to take material (soil samples, test tubes…); when supervising the performance of the procedure and when observing the results (if they had properly followed the phases) and to ensure that they understood and completed the field notebook. Finally, two interpreters were present. Their functions, in addition to translating and ensuring that the signers understood the explanations of the teacher and the other DHH oral language users, were to translate the contributions that the signers wanted to share with the group.
- Linguistic support: Two types of support were envisaged depending on the linguistic code of the participants. For oral DHH people, messages were conveyed in short, clear, and complete sentences. For signers, interpreters translated/explained the messages in sign language. Oral explanations were often supported by digitally presented visual material (Figure 1), and pauses were made for them to pay attention to the visual material (soil, specimens, and images shown) and then to the verbal content. In other words, the strategy was designed to mitigate the effects of their divided attention. In addition, scientific terms were introduced from the knowledge of common words (e.g., "permeability" from the word impermeable, a fairly common word known to many); words that usually have another meaning in everyday life ("a/to sample" both verb and noun) were associated with objects and images that represent new scientific meaning (e.g., soil sample), in order to undo the misunderstanding; and/or specific vocabulary was included after experimentation with them (e.g., the three soil types: sandy clayey, and silty-loam).
- Visual aids: Visual aids were shared at two points in time. Firstly, the teacher shared them with the large group. They consisted of a digital presentation that complemented the conversation-explanation with the large group; as the sample of working materials to be used. Secondly, the other form of support consisted of a pictographic scheme representing the materials and the sequence of steps they had to carry out during the process of experimentation (Figure 2). This diagram was kept by each group at its table. In this way, if a participant found it difficult to understand the messages or to keep the information alive in the working memory, the sequence of steps could be revisited, so that the children could independently review and observe previous steps.

4. Results and discussion

At the end of the workshop, the extent to which the activities were designed and implemented to ensure access and active participation among DHH learners was evaluated. The design, as described above, took into account the defining characteristics of the diversity of DHH people and thus the most relevant support and methodology could be considered. Such a careful analysis and design generally yielded good results. Firstly, the results reflected the high degree of satisfaction with the workshop (Question 1) among the child participants, with learning science through experimentation (Question 2), with the way the workshop was conducted (Question 3), and with the subject matter (Question 4). When asked if they would be interested in learning science in this way, 11 of the 13 children who responded said yes. These high levels of satisfaction were reinforced by the 12 valid answers given to the question regarding the content of the workshop (Figure 3).

FIGURE 1
Example of digitally visual material.

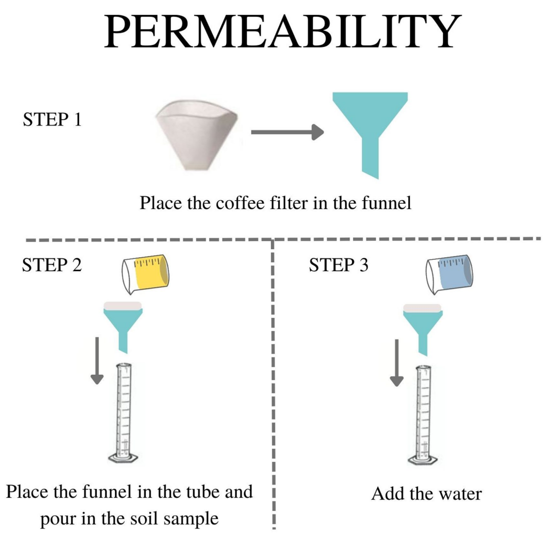

FIGURE 2
Example of a pictographic scheme representing the materials and the sequence of the experimentation process.

These results can be interpreted as a good indicator to continue with projects that follow this line of action in terms of the methodology and the supporting material and aids that were used. Opening up safe and caring spaces for non-formal science education will ease the initial reluctance of DHH children to engage in this type of science activity outside the school context. The belief that such spaces are not for them; the lack of training of the people in charge of these spaces; and the lack of support that fits their characteristics (Fisher et al., 2022) are the elements that generate reluctance.

The following is a description of the successes and failures detected during the development of the workshop in the six previously established indicators, based on direct observation by two of the researchers of the study and the contributions of the professionals from the association of DHH during the interview.

4.1. Space organization and divided attention

The application of strategies that considered the sequential processing of information from the environment was one of the aspects valued by the interpreters, since regardless of their degree of hearing, DHH children receive information from the environment through the visual channel as a matter of priority.

Thus, presenting the explanation-dialogue on the subject first and then asking participants to pick up the working materials was effective for three reasons. Firstly, it breaks the dynamic of listening and lets the participants have a breather, which reduces mental fatigue. Secondly, because if they had the materials accessible on their table before the explanation, they would have started to work them and it would have been more difficult to focus their attention on the initial dialogue and explanation. Finally, because it is one way to counter problems of divided attention as one of the interviewees pointed:

> When we are in the workshops, first you have to share all the information and then do the experiment and you cannot do both things at the same time when the child is looking at you. If they start doing the experiment, they stop listening and stop looking at the interpreter (I2).

The ideal situation, as developed in the workshop and highlighted as positive among the professionals from the association, is therefore to catch the attention of all children to explain what must be done, to distribute the necessary material to carry out the experimental work, and then to give the children time to carry out the previously explained task.

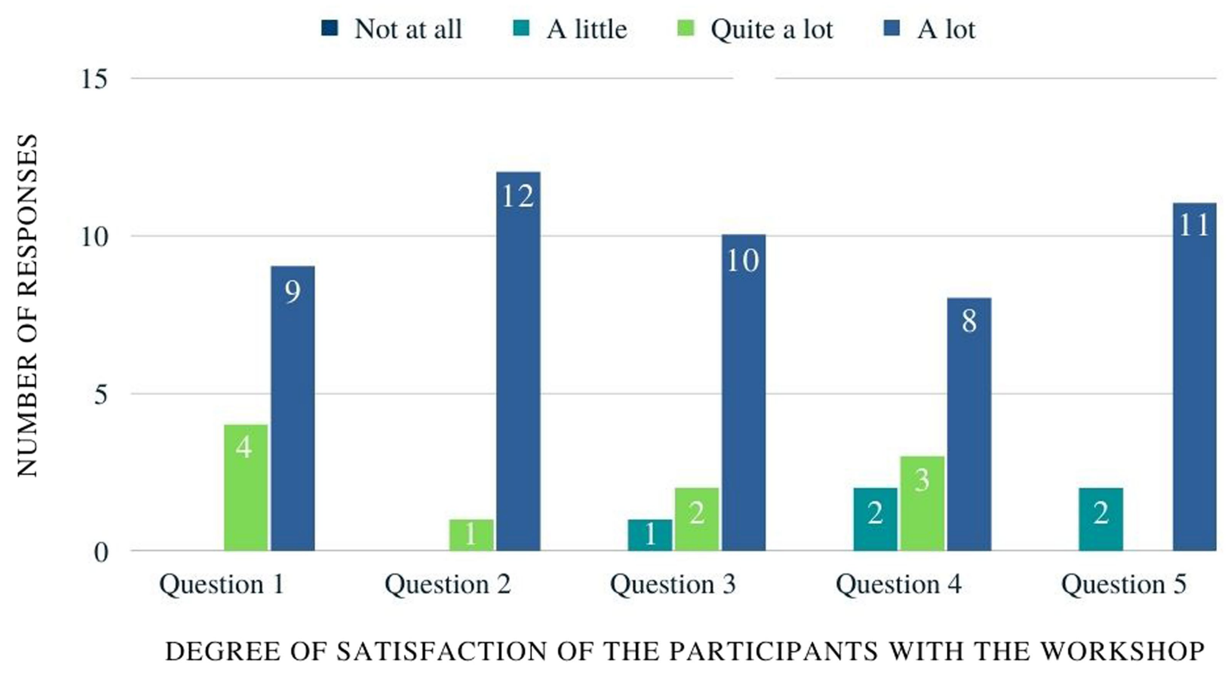

FIGURE 3
Degree of satisfaction of the child participants with the workshop.

However, not all details concerning divided attention that the researchers observed during the workshop were taken into account. The interpreter was integrated into the group of DHH signers as the session progressed. However, it might have been more appropriate to have placed the instructor, materials, and interpreter on the same plane in order to access all the information offered by the instructor to the large group (instructor's comments and the visual support of the digital screen and the objects shown). In other words, one of the interpreters should have stood alongside the person leading the workshop, in front of the screen where the visual aids were and should have pointed to the images or objects as appropriate. Nevertheless, the location of the interpreters during the small group task was ideal.

4.2. Auditory fatigue

The evaluation of the professionals from the association who attended the workshop also focused on highlighting the appropriate structure of the workshop, which combined in a balanced way the time devoted to explanation and the time devoted to action, that is, to the process of experimentation and dialogue, which avoided auditory fatigue of the participants.

> I liked what you did because it was a part of explanation and then you had to do a task (I2).

The interpreters stressed the need to avoid long oral and written explanations, as it implies overexertion for DHH children:

> DHH children suffer from [hearing fatigue] all the time when they have to spend 8 hours listening to what the teacher is saying (I3).

The avoidance of this auditory fatigue appears to be directly related to the use of the inquiry methodology, as revealed by direct observation. Throughout the workshop, the active and dynamic nature of the inquiry methodology helped the participants to stay engaged with the rhythm of the workshop. Many of the barriers to participation and learning were overcome by placing the learner at the center of the learning process, thus replacing teacher-centered teaching processes and the one-way transmission of information and knowledge.

This approach also opens the door to contextualized and concrete learning; in other words, the theoretical explanation is materialized in such a way that abstract theoretical concepts, such as "the degree of permeability of the soil," can be observed and reflected upon through experimentation. It is an approach through which one of the major difficulties of DHH children in science classes can be overcome: the understanding of abstract concepts (Sousa and Silveira, 2011; Oliveira et al., 2012). This reality appears in the testimony of one of the specialists:

> If we had put these contents in a book that we had to study, put it in our head and then put it away, the contents would be forgotten… Not in these cases [through experimentation] (I2).

4.3. Language and dialogue

The management of language and dialogue during the session was of great importance in the design of the sequence, because of its relevant role in the learning process of DHH people and in the development of self-confidence to interact and share knowledge (Molander et al., 2010).

The introduction of key vocabulary was done at the beginning of the workshop, during both the presentation and the explanation of the experimental processes. This vocabulary was reinforced with images; through associations with commonly used words [permeable/(im) permeable clothing], and by analyzing polysemous words (to sample as a verb and sample as an example of something). This strategy could have been reinforced with the use of vocabulary glossaries (Santana and Sofiato, 2018) that might have included, in addition to the list of signs included in the topic, their corresponding image and the written word. In this way, signer learners would have had a reference and support to incorporate these new concepts in their discourse; references and support that their oral language user peers could also access.

However, the creation of this glossary would have required prior coordination between the researchers in charge of designing the workshop and the sign language interpreters who attended the workshop. This would also solve the recurrent problem they face when translating scientific terminology, which is often unknown to them (Molena et al., 2017). Moreover, in future experiences, the key vocabulary (represented through the word, the image, and the sign) should be visible throughout the workshop, as difficulties were observed in the children's incorporation of those terms into their explanations.

4.4. Visual support

With regard to visual aids, the digital presentation that accompanied the oral messages of the instructor in the large group was effective, as it was continuously used to reinforce the explanations. It meant that the children could understand and follow the thread of the explanation more easily. However, the participants were unable to use the pictographic diagrams depicting the phases of the experimental process (Figure 3) very well, because they were not properly explained. Thus, after the presentation of each of the three experiments, the visual diagrams that each group had on their table should have been introduced and their function explained. In this way, they would have known when the visual diagrams could have helped them and for what purpose. On the other hand, they should also have been reminded of visual diagrams at key moments to prevent them from losing the thread of the activity and their dependence on the instructor and/or the interpreters, thus achieving greater autonomy throughout the process.

4.5. Methodology of scientific inquiry

Finally, although the choice of a guided inquiry was neat, fun, and effective (Martin-Hansen, 2002), the limited duration of the workshop made any explicit explanation of the dynamics of scientific inquiry and its various steps impossible. This explanation would have allowed a better understanding of how scientific knowledge is generated, as well as a greater emphasis on what they have to observe, in order to establish clearer relationships and to facilitate the argumentation of the knowledge that was generated. This shortcoming was identified mainly because of difficulties in expressing the results obtained and in drawing general conclusions in response to the research question.

It is therefore considered necessary to invest more time in reflecting upon and explaining what is observed. This can be done by interspersing the small group comments with large group interventions, to ensure understanding and to be able to provide them with a complete explanatory-argumentative model of all scientific activity that is observed. It is true that reflecting upon and discussing these structural and functional aspects of the generation of scientific knowledge, so important for the development of scientific competence (Enderle et al., 2020), goes beyond the real objectives and possibilities of this workshop. Nevertheless, if the inquiry methodology is to be used in activities of longer duration, this sort of discussion is indispensable.

5. Acknowledgement of conceptual and methodological limitations

This work is necessarily limited by the uniqueness of the case study, a single workshop for a small group of DHH children. It will therefore be necessary to expand the number of workshops in order to evaluate the effectiveness of the psycho-pedagogical supports in use. Conceptually, the perspective from which this study was designed, implemented, and analyzed may had been affected by the absence of a DHH person on the working team. A contribution that would have significantly strengthened the study providing a more accurate viewpoint.

In methodological terms, although the questionnaires completed by the participating children allowed us to know their opinions, it is necessary to bear in mind possible bias of their answers. Contextual and personal factors may influence the answers provided, such as their role in the peer group, their self-esteem, or their self-concept. Consequently, it would have been more appropriate and revealing to familiarize ourselves with their opinions in a more in-depth and detailed way, for example, through group dynamics and by asking them what interested them most and why; and what they liked the least and why. In other words, if the participants themselves had been encouraged to indicate what did and did not suit them, then any subsequent modifications would have had a more solid foundation.

Finally, it is worth stressing that the wide age range of the group was a challenge during the design and implementation of the sequence; and a limitation for the study, since the results obtained were not analyzed according to this variable.

6. Final conclusion

Ensuring access, participation and learning for all people in non-formal activities must be a priority for the organizations responsible for their development (Fisher et al., 2022). To this end, it is necessary to analyze the space, the activities designed, the attitudes of the staff, and the resources available to identify which aspects may be considered as barriers to remove them all and to provide appropriate support (Ainscow, 2005). This process of reconstruction would ensure equal opportunities for all people regardless of their personal, social, economic, and cultural characteristics that contributes to reducing inequalities (Yasunaga, 2014).

During the implementation of *Science on Saturdays*, an extracurricular project created with the aim of contributing to increasing children's interest in science and the didactic competences of future teachers, was identified the need to rethink its functioning to make it a project of all and for all.

This study reflects part of this process, identifying the most appropriate psycho-pedagogical supports for a group of DHH children to participate in a non-formal science activity actively. The results point to the suitability of using a dynamic and flexible methodology, such as scientific inquiry, which allows children to actively apprehend a scientific concept or phenomenon from different learning experiences. The observation, manipulation, analysis, and dialogue activities compensate for the theoretical content load, which reduces the mental fatigue of lengthy theoretical explanations.

Furthermore, using strategies that respect the needs regarding divided attention through a precise organization of space and sequencing of the activity avoids the loss of shared information, and well-integrated visual supports during the activity reinforce the oral and sign explanations and give greater autonomy to the children during the process.

The development of this experience raises new challenges and objectives. Boosting and stabilizing the presence of people with functional diversity in non-formal education activities (Dymond et al., 2020) would require the presence of experts in the working groups to advise on the measures needed to create truly inclusive spaces. However, it would also be necessary to promote studies such as those carried out by Pita-Carmo and Massarani (2022a) to highlight the preferences and demands of the population who encounter barriers to access and participation so the organizations responsible for these spaces and activities can incorporate them.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by Bioethics Commission of the University of Burgos. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

Author contributions

EM conceived the idea. EM, IM, GS, and MD contributed to the study design. EM and GS collected the data. EM and MD organized the database. EM and GS wrote the first draft of the manuscript. EM and IM analysed and introduced the improvements suggested by the reviewers. EM wrote the final version of the manuscript. All authors contributed to manuscript revision, read, and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

Ainscow, M. (2005). Understanding the development of inclusive education system. *Electron. J. Res. Educ. Psychol.* 3, 5–20.

Cabalé-Miranda, E., and Rodríguez-Pérez de Agreda, G. M. (2017). Educación no Formal: potencialidades y valor socia. *Rev. Cubana Educ. Sup.* 36, 69–83.

CNSE (2021). Manifiesto de la Confederación Estatal de Personas Sordas (CNSE) por la semana internacional de las personas sordas. CNSE. Available at: https://cnse.es/index.php/noticias/item/774-semana-internacional-de-las-personas-sordas-2021 (Accessed January 3, 2023).

Coll, C., Esteban-Guitart, M., and Iglesias-Vidal, E. (2020). *Aprendizaje con Sentido y Valor Personal, Experiencias, Recursos y Estrategias de Personalización Educativa*. Barcelona: Graó

Colom, A. (2005). Continuidad y complementariedad entre la educación formal y no formal. *Rev. Educ.* 338, 9–22.

Couso, D., Jiménez-Liso, M. R., Refojo, C., and Sacristán, J. A. (2020). *Enseñando Ciencia con Ciencia*. Madrid: Penguin Random House

Dias, L., Mariani, R., Delou, C., Winagraski, E., Carvalho, H., and Castro, H. (2014). Deafness and the educational rights: a brief review through a Brazilian perspective. *Creat. Educ.* 05, 491–500. doi: 10.4236/ce.2014.57058

Domínguez, A. B. (2009). Educación para la inclusión de alumnos sordos. *Rev. Latinoam. Inclus. Educ.* 3, 45–51.

Duarte, I., Costa-Santos, C., Rego, G., and Nunes, R. (2016). School failure in students who are normal-hearing or deaf: with or without cochlear implants. *Springerplus* 5, 237–238. doi: 10.1186/s40064-016-1927-9

Dymond, S. K., Rooney-Kron, M., Burke, M. M., and Agran, M. (2020). Characteristics of secondary age students with intellectual disability who participate in school-sponsored extracurricular activities. *J. Spec. Educ.* 54, 51–62. doi: 10.1177/0022466919851194

Enderle, P., Cohen, S., and Scott, J. (2020). Communicating about science and engineering practices and the nature of science: an exploration of American sign language resources. *J. Res. Sci. Teach.* 57, 968–995. doi: 10.1002/tea.21619

European Commission (2007). *Science Education Now: A Renewed Pedagogy for the Future of Europe*. Luxembourg: Office for Official Publications of the European Communities

Fisher, K. M., Shannon-Baker, P., Greer, K., and Serianni, B. (2022). Perspectives of students with disabilities and their parents on influences and barriers to joining and staying in extracurricular STEM activities. *J. Spec. Educ.* 56, 110–120. doi: 10.1177/00224669211054109

Gil, J. L., León, J. L., and Morales, M. (2017). Los paradigmas de investigación educativa, desde una perspectiva crítica. *Rev. Conrado* 13, 72–74.

Greca, I. M., Diez-Ojeda, M., and García-Terceño, E. M. (2020). Evaluación del impacto social de un proyecto de educación no formal en ciencias. *Educ. Soc.* 41, 1–21. doi: 10.1590/es.230450

Hagevik, R., Woolsey, M. L., and Graham, S. (2011). "Science—a missing element: results of a time allocation study of elementary students who are deaf or hard of hearing." in *Annual meeting of American Educational Research Association*. New Orleans, April 8–12. 2011. Available at: file:///C:/users/emgterceno/downloads/18423.1.pdf (Accessed October 28, 2022).

Kurz, K., Schick, B., and Hauser, P. (2015). Deaf children's science content learning in direct instruction versus interpreted instruction. *J. Sci. Educ. Stud. Disab.* 18, 23–37. doi: 10.14448/jsesd.07.0003

Lomber, S. (2017). What is the function of auditory cortex when it develops in the absence of acoustic input? *Cogn. Dev.* 42, 49–61. doi: 10.1016/j.cogdev.2017.02.007

Lynch, S., Taymans, J., Watson, W. A., Ochsendorf, R. J., Pyke, C., and Szesze, M. J. (2007). Effectiveness of a highly rated science curriculum unit for students with disabilities in general education classrooms. *Except. Child.* 73, 202–223. doi: 10.1177/001440290707300205

Marschark, M., and Knoors, H. (2012). Educating deaf children: language, cognition, and learning. *Deaf. Educ. Int.* 14, 136–160. doi: 10.1179/1557069X12Y.0000000010

Martin-Hansen, L. (2002). Defining inquiry. *Sci. Teach.* 69, 34–37.

McGinnis, J. R., and Kahn, S. (2014). "Special needs and talent in science learning" in *Handbook of Research on Science Education*. eds. N. Lederman and S. Abell, vol. *2* (Routledge: New York, NY), 237–259.

Molander, B., Halldén, O., and Lindahl, C. (2010). Ambiguity – a tool or obstacle for joint productive dialogue activity in deaf and hearing students' reasoning about ecology. *Int. J. Educ. Res.* 49, 33–47. doi: 10.1016/j.ijer.2010.05.005

Molena, J. C., and de Andrade, P. G., and, Veraszto, E. V. (2017). Indicadores da inclusão de alunos surdos em salas de aula regulares. *Rev. Electrón. Enseñan. Ciencias* 16, 257–279.

Oliveira, W. D., Melo, A. C. C., and Benite, A. M. C. (2012). Ensino de ciências para deficientes auditivos: um estudo sobre a produção de narrativas em classes regulares inclusivas. *Rev. Electrón. Invest. Educ. Ciencias* 7, 1–9.

Pita-Carmo, M., and Massarani, L. (2022b). "Talking about science: deaf experiences of visiting science museums in Rio de Janeiro." in *XX IOSTE International Symposium 2022* (Recife). Available at: https://proceedings.science/ioste-2022/papers/talking-about-science-deaf-experiences-of-visiting-science-museums-in-rio-de-jan?lang=en

Pita-Carmo, M., and Massarani, L. (2022a). Acessibilidade e museus de ciências: visitação de jovens surdos a três museus do Rio De Janeiro. *Pesqui. em Educ. em Ciências* 24, 1–18. doi: 10.1590/1983-21172022240126

Raven, S., and Whitman, G. M. (2019). Science in silence: how educators of the deaf and hard-of-hearing teach science. *Res. Sci. Educ.* 49, 1001–1012. doi: 10.1007/s11165-019-9847-7

Santana, R. S., and Sofiato, C. G. (2018). O estado da arte das pesquisas sobre o ensino de ciências para estudantes surdos. *Práxis Educ.* 13, 596–616. doi: 10.5212/PraxEduc.v.13i2.0019

Schoffstall, S., Cawthon, S., Dickson, D., Bond, M., Ocuto, O., and Ge, J. (2016). The impact of high school extracurricular involvement on the postsecondary outcomes of deaf and hard-of-hearing youth. *J. Postsec. Educ. Disab.* 29, 179–197.

Sousa, S. F., and Silveira, H. E. (2011). Terminologias químicas em libras: a utilização de sinais na aprendizagem de alunos surdos. *Quím. Nova Escola* 33, 37–46.

Stake, R. (1995). *The Art of Case Study Research*. Thousand oaks, California: Sage

Vázquez, S. (2019). ¿De qué hablamos cuando "hablamos ciencias" en el aula inclusiva con alumnado sordo? *Rev. Estud. Lenguas Signos Aspect. Lingüíst. Adquis. Lenguas Signos* 1, 269–288.

Yasunaga, M. (2014). *Non-Formal Education as a Means to Meet Learning Needs of Out-Of-School Children and Adolescents*. Montreal: UNESCO Institute for Statistics

Yin, R. (2009). *Case Study Research: Design and Methods*. Thousand oaks, California: Sage.