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Analysis of an accessibility strategy for deaf people: Videos on a traveling science center

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Introduction: Brazilian traveling science centers have difficulties in providing sign language accessibility to the deaf people that visit them. The main objective of this study was to analyze the contribution of accessible video guides in Brazilian Sign Language (BSL) in helping deaf visitors understand the activities proposed by the traveling science center "*Ciências Sob Tendas*".

Methods: This research used a critical quali-quantitative approach that involved 128 deaf students from middle and high schools. Data were gathered via an online survey and video recording.

Results and discussion: The results indicated successful use of the video guides by deaf participants. Within this specific research, in which 745 questionnaires were answered, we found that the videos, along with interactive activities, contributed to the interest, curiosity, and understanding of the themes presented. Furthermore, the return visits of deaf people to revisit activities a second and third time may indicate the potential of this science communication strategy to stimulate their interest in scientific knowledge. However, 15% of responses showed that they had some difficulty understanding the video's explanation. This may indicate that, although videos are a well-accepted alternative for accessibility, the presence of an interpreter guide or a deaf visitor guide, when possible, is ideal. Essentially, a professional interpreter can use several BSL resources and strategies to make themselves understood.

Conclusion: Thus, we considered that accessible video guides in BSL are a viable resource for providing accessibility to deaf people in traveling science centers.

KEYWORDS

deafness, sign language, video guide, inclusion, traveling science center, science communication

1. Introduction

Traveling science centers are places for non-formal education. They present scientific and academic knowledge to people in an easier and more playful way. Science communication in such places contributes to the dissemination of knowledge, stimulates curiosity, and, perhaps, the search for more knowledge in children, youth, and adults (Alves et al., 2020; Rocha et al., 2020; Ferreira, 2021b).

In Brazil, many traveling science centers are initiatives of universities or public institutions, and more often than not, these institutions have a very tight budget. To make them possible, creative and low-cost solutions are a way of carrying out their activities (Alves et al., 2020; Rocha et al., 2020; Ferreira, 2021b).

Ciências Sob Tendas (Science Under Tents or CST) is a traveling science center from Fluminense Federal University. It has more than 30 playful and interactive activities which can be included in one or more of its four verticals: Humanities, Health, Nature, and Technologies (Alves et al., 2020). CST, like other traveling science centers in Brazil, faces the challenge of providing accessibility for visiting deaf people. Usually, this difficulty is due to a lack of people who have mastered Brazilian Sign Language (BSL). Nonetheless, most traveling science centers work with volunteer explainers during the expositions. The explainer has the role of assisting the visitor in understanding the exhibition or proposed activity. To this end, questions and dialogues with the visitor are promoted to use their knowledge and experiences to create a link with the displayed content (Alves et al., 2020; Rocha et al., 2020; Ferreira, 2021b). Also, financial resources are not abundant; therefore, accessibility strategies that are not expensive must be used.

The itinerant nature of traveling science centers has its singularities, since they come into contact with different territories and people with varied cultural backgrounds and life experiences (Alves et al., 2020; Rocha et al., 2020). In Brazil, many deaf people do not have the chance to live within deaf communities, especially in the countryside, which further increases inequality and exclusion (Perlin, 2016). According to the National Health Survey conducted by the Brazilian Institute of Geography and Statistics (IBGE, 2019), about 2.252 million people in Brazil are hard of hearing. Of these, only 133,000 have completed higher education, approximately 327,000 have an incomplete higher education, 194,000 have an incomplete high school, and 1.598 million do not have any academic education. Therefore, it is important to ensure access for deaf people to the knowledge presented by the traveling science centers.

Many deaf people come from hearing families that do not master sign language, which causes delays in acquiring linguistic knowledge. After all, in the family environment, some exchanges contribute to the knowledge of new terms and concepts. The BSL makes it possible for deaf people to develop the abstraction of these terms through their respective signs and the representation of symbols. In the absence of dialogue and linguistic exchange, "learning and communication are compromised" (Costa, 2021, p. 21).

Perlin (2016) showed that life's paths and experiences contribute to the development of different personal profiles and identities of deaf people. She emphasized that there is not just one kind of deaf person. In fact, in her research, she indicated that every deaf person is complex and multifaceted and varies from others in several ways due to early experiences. They are marked by their exchanges and relationships with other deaf people and hearing individuals. Perlin explained that some deaf people recognize themselves as deaf from an early age, live in deaf communities, and learn sign language from birth. However, there are also some who do not speak the dominant oral language of the country or sign language. They use basic familiar communication as they do not live with their deaf peers but come from hearing families and live in this environment. Then, there are some deaf people who learn to speak and read lips and later discover deaf communities and sign language. There are many other different life paths that may shape a deaf person's identity.

As a result, some deaf people have better communicative understanding in their mother tongue and first language (L1) and BSL but have difficulty establishing relationships between texts in Portuguese; others know written Portuguese better than sign language, and some even have difficulty with both languages. Therefore, it is often necessary to provide accessibility through bilingual deaf people or bilingual hearing people who can explain, with sign language, what is written in Portuguese or what is been said orally by a tour guide (Oliveira, 2014; Perlin, 2016; Ferreira, 2021c; Medeiros Portella et al., 2021).

Costa (2021) states that educational inclusion has been the subject of extensive discussion in our society, reinforced by a Student Inclusion Policy, which defends quality teaching for the student while respecting their specificities, as in the Law of Guidelines and Bases of National Education (Brasil, 1996). According to Costa, inclusive education has not yet offered adequate conditions for deaf students to enable their academic/educational development. The lack of fluency in BSL by teachers undermines the teaching and learning process. Thus, the situation in many schools is that the teaching is done orally in Portuguese and the content is translated by an interpreter or, in the absence of an interpreter, the student is required to lip-read. The difficulty encountered by students can cause them to either fail school or be approved and moved up a grade even without achieving the expected results, which only covers up the existing difficulties (Costa, 2021).

Some museums have implemented multimedia resources to provide accessibility for deaf visitors (Proctor, 2005; Fernandes et al., 2020; Rocha et al., 2020; Ferreira and Alves, 2021). A video guide in sign language is a multimedia resource that requires equipment for its production: a studio with a chroma key, a camera or cell phone, adequate lighting, a person who knows sign language, and a video editor. As the production of such videos does not involve the need to maintain a regularly hired interpreter nor a specialized firm, we believe that it is a possible resource to be used in the exhibition environments of traveling science centers. Also, this video guide needs to contemplate the largest audience possible, and, as there are still no established parameters for traveling science center guide video elaboration, research on the perceptions of deaf visitors regarding this resource is relevant to improve this form of accessibility.

This study, therefore, intended to analyze whether the accessible video guides in BSL that are available in CST's exhibitions contribute to the understanding of activities and encourage deaf people to interact with these activities with autonomy.

2. Material and methods

A mixed-method approach was used to evaluate the effects of a project that provided BSL videos for a traveling science center. The quantitative part was the results of a survey on the use of

videos while the qualitative part used a thematic analysis to identify themes of an open question about the research. This type of research focuses on highlighting the strengths and weaknesses of the experience for a specific audience, in this case, deaf visitors at the traveling science center Ciências Sob Tendas (Brandão, 1999; Minayo, 2001; Kellaghan, 2010).

2.1. Research subjects

The interior of the city of Rio de Janeiro is divided into four regions: the North Zone, South Zone, West Zone, and Center. The State of Rio de Janeiro also has some divisions, including the Baixada Fluminense and the Metropolitan East. The Baixada Fluminense corresponds to the territory located in the north of the municipality of Rio de Janeiro. The Baixada Fluminense consists of 13 municipalities: Belford Roxo, Duque de Caxias, Guapimirim, Itaguaí, Japeri, Magé, Mesquita, Nilópolis, Nova Iguaçu, Paracambi, Queimados, São João de Meriti, and Seropédica. The Metropolitan East is the territory located in the east of Guanabara Bay, composed of five municipalities: Niterói, São Gonçalo, Itaboraí, Tanguá, and Maricá.

The National Institute of Education for the Deaf (INES) has 388 students enrolled from kindergarten to high school. Approximately 272 of these students are from Rio de Janeiro city (150 from the North Zone, 64 from the West Zone, 30 from the Center, and 28 from the South Zone). The other 116 are from the 14 cities near Rio de Janeiro. In 2022, the INES had 160 students in middle school (MS) and high school (HS) for the morning sessions.[1] From these 160 students, 128 of them participated in this research. The students were duly informed about how the research would be conducted. They agreed to take part voluntarily and signed the Image Authorization Document and the Free and Informed Consent Term (FICT) in the case of minors or the Free and Clarified Consent Term (FCCT) for adults and those responsible for the minors.

2.2. Research application instruments

2.2.1. The explanatory videos in BSL

The BSL video guides were produced by the researchers, in consultation (since their initial phase) with a deaf woman fluent in BSL and with a Ph.D in linguistics. After being produced, the videos were presented to a group of 30 deaf people to evaluate the following features: explanation, content, interpretation, and background color. Based on the validation data, the videos were improved and used in the present research. The validation procedure was conducted totally online as the group did not have the opportunity to perform the activities in person due to the COVID-19 pandemic (Ferreira, 2021a).

On the table of each activity, there were two Samsung Galaxy Tab A7 tablets with explanatory videos of that activity available offline on Google Drive. Each video was accessed by scanning a QR Code. The QR Codes had an identification of the background color to which the video corresponded and were arranged side by side at the bottom of the folder along with the title and explanation of the activity. The folder was positioned on top of the activity table supported by an acrylic stand (Supplementary Figure 1).

Each activity was explained in BSL through a video with four different background options: black, white, green, and blue (Supplementary Table 1). These backgrounds were chosen based on the previous validation process for the videos, in which blue and green backgrounds were identified as those preferred by the deaf participants. The black and white backgrounds were indicated by deaf people as the best colors for deaf people with low vision or deafblind people (Ferreira, 2021a). The videos had explanations in BSL and subtitles at the bottom with words in capital letters for which fingerspelling (writing words with a manual alphabet) was done. In addition, there was insertion of illustrative images of the technical terms, as well as greater use of classifiers[2] and an image description[3] to improve understanding (Ferreira, 2021a).

Some videos were divided into three simple parts. In the first part, the visitor would watch how to perform a certain activity. After that, the video started a countdown at which moment the visitor was supposed to pause the video and do the activity on their own. Upon finishing the activity, the visitor would resume the video and watch the explanation of the science behind the activity. However, there were more activities than explainers and, sometimes the explainers were preoccupied with helping a particular visitor to perform the activity. Thus, it is possible that some participants had watched the entire video at once and listened to the explanation before carrying out the activity. This perhaps could have interfered with the fluidity of the activity and the participant's own spontaneity.

2.2.2. Dynamics of the data collection

To perform the research, we contacted the school board requesting authorization and to schedule dates. With this defined, we went to the school during the enrollment renewal period to talk to those responsible for the students. We explained how and when the research would be done, clarified any questions they had, and obtained their signatures on the documents to authorize the participation of underage students.

We stipulated that all students from the 6th grade to the 12th grade could participate in the research. The only requirements were

1 In Brazil, school hours run from 8 a.m. to 12 p.m. for morning sessions; an afternoon session to a different group of students starts from 1p.m. to 5 p.m.; and most schools also offer a night class running from 6 p.m. to 10 p.m.

2 Classifiers (CL), in sign language, are usually associated with nouns, verbs, or adjectives. CL are used to describe an object or creature (its size, shape, or texture), to specify behavior or action, to indicate the way in which certain instruments/tools are used and/or to indicate the plural or location of something (Lira et al., 2021).

3 Image Description (ID) is a term used by Campello (2008) referring to transferring an iconic representation of what it refers to the signer's body. For this, there is the use of facial and body expression and CL expressions, forming a visual image with its meaning. In this way, when seeing a representation of a sign on a person's body, the visual record is so clear that the concept can be seen without the need for illustrative images (Lira et al., 2021).

to have signed the requested documents, be deaf, and to be within this level of education. These criteria were established thinking about the time we had available to apply the research on-site and the number of classes that would be part of the research.

One month before the research application, we returned to the institution to explain the research to the teachers and for them to allow the students to participate in the activities during class hours. In this same time frame, we went into each classroom and explained the research to the students, emphasizing that participation was voluntary without any burden for those who had no interest. The students who were interested signed the requested documents right after the explanation of the research.

On the day of the exhibition, the students were brought classwise in groups of 10 to 16 students to participate in the activities over the course of 1 h. As soon as they arrived, the students signed an attendance list, in which we checked if the student had signed the FCCT or FICT and the Image Authorization. If not, we asked them to sign before entering to perform the activities. Students could then go to one of the activities. There was no monitoring or requirement to carry out all the activities.

Upon arriving at the activity table, a tablet was provided and the explainer guided the visitors to scan the QR Code of the activity (Supplementary Figure 2). The visitors watched the explanation presented in the video in BSL (Supplementary Figure 3). Then, they performed the activity with the help of the explainer, whenever necessary (Supplementary Figure 4). After completing the activity, the explainer returned the tablet back to the visitors to scan the QR Code of the questionnaire (Supplementary Figure 5). The visitors first answered the questionnaire (Supplementary Figure 6), following which, if they had any questions, they could ask the listener (explainer) or the researcher fluent in BSL and present at the site every day. If not, the tablet was left on the activity table and the visitors went to the next activity and went through the same process.

2.2.3. The exhibition activities

The CST exhibition had 11 activities presented over six working days, through the last Friday of April and the first week of May 2022. Two explainers assisted in undertaking six activities, which were as follows:

(a) Secret Writing: the visitor sees how colors are formed by combining blue, green, and red lights on a cellphone screen. They find hidden images using blue and red filters, and, after that, they are invited to write a message and hide it using the same color filters;
(b) 3D Printer: the visitor sees how 3D printing is done. The process is explained along with its possible applications in medical, construction, and design fields;
(c) Paper that Sprouts: the participant is tasked with a process similar to paper recycling and discovers that the new paper has seeds in it which they can plant after using it;
(d) Knowing your Cells: the participant collects cells from their oral mucosa and observes it under a microscope, attempting to identify its membrane, cytoplasm, and nucleus;
(e) Ozobot: the visitor is first briefed about the different uses of robots to streamline business processes, construction, surgery, and agriculture. Then, the visitor is invited to organize the commands so that the robot, an Ozobot model, follows an established course;
(f) Painting the Body: after being informed of the characteristics and main functions of the brain, the visitor paints with regular paint a small model of the brain in plaster.

The remaining five activities involved manipulation and observation of the experiments. These did not require a step-by-step process. There was only one explainer for every two activities, which were as follows:

(a) Ramp: the visitor is asked in which of the two ramps, one curved and one straight, the ball will reach the endpoint first. After answering, the visitor switches a lever, watches two balls descend in their respective ramps, and then receives the physics explanation of the observed phenomenon;
(b) Discovering Microplastics: the visitor observes and manipulates different materials that contain microplastics. Then, the visitor watches an explanation about the possible consequences of this type of waste on the environment and what the alternatives are to replace microplastics;
(c) Virtual Reality: after watching an explanation of possible pathologies when neurons are affected, the visitor 'enters' the human brain using virtual reality glasses and fights the diseases in the neurons;
(d) Arthropods: the visitor can manipulate and observe several arthropods in resin, see a scorpion's exoskeleton under black light, and watch an explanation about the influence of these animals on the environment, agriculture, and bio-economy;
(e) Comparative Anatomy: the participant manipulates plastinated parts of human and animal bodies and watches the explanation about each one of them.

The explainer responsible for the "Comparative Anatomy" activity also registered the student's attendance.

It is important to emphasize that the explainers were listeners, volunteers, and undergraduate students who work at CST. Although the role of explainers in a science center is to dialogue with the participants about the activities and assist in their execution, in our research they only acted as a facilitator during the execution of activities. The explainers also did not know BSL; therefore, they could not explain the activities. However, prior to the research application, they were instructed with basic signs of "READ QR CODE", "RESPOND QUESTIONNAIRE", "AGAIN, ANSWER QUESTIONNAIRE" and "YES, PLEASE".

2.2.4. Data collection methodology: Questionnaire

After watching the video and participating in the activity, the students were invited to answer the questionnaire by scanning a QR code to access it on Google Forms. After saving their responses, they were instructed to leave the tablet on the table and move on to the next activity. The participants were asked to

answer all the questions, even the initial (profile) questions, in every activity. This was necessary because, as the activity videos were available offline, the tablet needed to be on the activity table, so that the participant could not use the same tablet to continue answering the questionnaire on the same form. It should be noted that not all students answered the questionnaires in all activities.

The questionnaire, with eight questions, was developed based on the opinion survey carried out by Proctor (2005) in a museum that used accessible video guides. All questions were written in Portuguese and had a video in BSL. Two questions were regarding the participant's profile: age and school grade. One question identified the activity the visitor had just participated in. Two questions were about the visitor's opinion regarding the videos in BSL, whether they had a negative or positive influence on their participation in the activity, and whether the explanation had been understood. One question sought to know whether access *via* QR Code was easy or difficult. One question was to determine whether the participant would be inclined to visit accessible spaces through video guides in BSL. Finally, there was an open-ended question for criticism and suggestions, which could be answered in written Portuguese or in BSL by filming themselves on a tablet or on a camera, a Nikon Coolpix 9,000 model, positioned on a tripod near the activities.

2.2.5. Data analysis processing

When the questionnaires were completed, Google Forms automatically grouped, quantified, and organized the data in Excel format. Data were presented in precise numbers and not in percentages.

All responses to the open-ended questions were also organized by topic—leaving all answers to the same question together—allowing it to be analyzed quantitatively and/or qualitatively. To identify the participants' answers to open-ended questions in written Portuguese and to maintain anonymity, we used the sequential numbers organized by Excel. For the answers filmed in BSL, we used letters of the alphabet to identify them.

Data from the answers to open-ended questions (written or in BSL) were evaluated through the thematization method proposed by Fontoura (2011). It is widely used as an instrument to analyze data in qualitative research because it allows for a better understanding and use of the collected data, especially in speeches or, in this case, gestures. Non-verbal communication such as facial expressions, gestures, silences, and sighs are also important factors of analysis, as they can complement the participants' statements (Fontoura, 2011).

Fontoura's thematization analysis has 7 steps:

1° – Transcript of the open answers. When the responses were in BSL, the videos were translated and transcribed. When the answers were in writing, they were gathered in an Excel table;
2° – Reading and observing responses to select the main focuses of each response;
3° – Delimitation of what is relevant. For this we sought the central ideas, the keywords, and the answers that most closely resembled each other and the ones that were most distinguished;
4° – Creation of groups of similar aspects. For this stage, we observed which answers followed/addressed a similar theme and grouped them together. This grouping process took into account the relevance of the themes for the purpose of the study carried out;
5° – Verification of responses that resemble to form a unit of meaning. From the gathering of what was similar, it was possible to identify, within each response, the unit of meaning. This made it possible to create themes and, in some cases, sub-themes that encompassed these units of meanings;
6° – Tabulation of the data in a categorized way. In this step, we organized the data into an Excel table. In Supplementary Table 2 we provide a part of the table for reader appreciation;
7° – Finally, interpretation of the data. At this stage, based on the pertinent theory, we carried out a reflection on the themes identified. We also compared the data of the closed responses with those of the open response to verify whether or not there was any correlation between these responses or even with the interactions that occurred during the activities. From there, we elaborated on the discussion and presented our perceptions and deductions.

Therefore, in our research, after the translation and transcription of the recorded responses, we (all the researchers of this article) performed a careful reading, observing which *in-vivo* codes could be extracted in each response as units of meaning. Based on those units of meaning, we, together, discussed and elaborated a descriptive coding (researcher-derived code); in other words, we summarized in a word or in an expression the participant responses' main idea(s). These summarized words or expressions become our themes and sub-themes. After analyzing all responses and choosing the words or expressions, we checked if they could be grouped into larger themes.

3. Results

3.1. Profile of the research subjects

We had 128 participants, 66 from middle school (MS) — 34 girls and 32 boys — and 62 from high school (HS) — 21 girls and 41 boys. Among MS students, ages ranged from 11 to 25 years; and among those from HS, ages ranged from 15 to 27 years old.

Among the 128 students who agreed to participate in this research, 93 of them lived within the city of Rio de Janeiro (54 in the North Zone, 10 in the South Zone, 24 in the West Zone, and five in the Center), 30 of them lived at Baixada Fluminense, and five of them in the East Metropolitan (Supplementary Table 3).

The eleven activities were visited by the students during the CST exhibition, and they were asked to answer the questionnaire after each one. Figure 1 shows how many questionnaires were answered in each activity. At the end of the 6 days of data collection, we gathered 745 completed questionnaires.

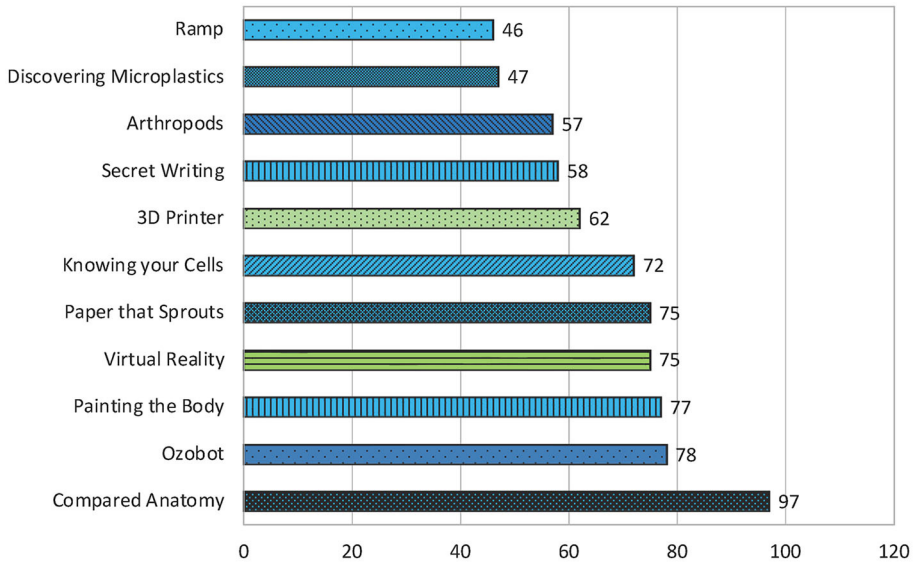

FIGURE 1
Actual number of students that answered the questionnaires in each activity n = 745.

3.2. Video access through QR Code

Regarding access to videos through QR Codes, we observed that, in 33% of responses (248 responses), the visitors had difficulty accessing them; approximately 37% of responses (273 responses) said they had some difficulty; 21% (155 responses) stated that they had no difficulty; approximately 3% (27 responses) stated that they did not know what a QR Code was; and 6% (42 responses) stated that they did not know how to answer (Figure 2).

3.3. The experience and understanding of the videos in BSL in the activities

The data showed that most responses (76%) considered that the videos in BSL enriched their experience in the activity. For 9% of the responses, the videos did not change the experience within the activity at all; for 7%, the videos hindered the experience of the activity; and 8% did not know how to answer the question (Figure 3). The results presented in isolated activities did not change in relation to the total (data not shown).

The enrichment in the activity's experience was directly related to the understanding of the explanation in BSL (Figure 4). Most of the responses indicated that those explanations were very easy to understand (53%) or relatively easy to understand (32%). We also observed that 7% found it difficult to understand, 5% found it very difficult to understand, and 3% did not understand at all.

When analyzing answers for the above question in each activity separately, we observed that, in most activities, ~49 to 62% of the responses stated that they understood the explanation very easily. However, there was a drop in understanding regarding the explanation for the "3D Printer" (44%) and "Discovering Microplastics" (39%) activities when compared with activities such as "Paper that Sprouts" (62%), "Ozobot" (60%), and "Knowing your Cells" (60%) (Table 1).

3.4. Would you visit a science center with video accessibility?

In our research, when asked which science center they would visit, whether one with BSL accessibility through videos or one without accessibility, we observed a large number of responses that chose the center with accessibility through BSL videos (57% responses). However, 23% stated that they would visit the science center without accessibility. Another 8% stated that they would visit both centers, with and without accessibility. Only 3% stated that they would not visit either of the two centers, and 8% could not answer (Figure 5).

We could also observe that, from those who chose to visit a museum without accessibility (equivalent to 173 questionnaires), there were 28 responses that considered the explanation difficult, very difficult, or did not understand it, and that the videos did not change the experience in the activity or even hindered the experience. In addition, of the 173 questionnaires, 100 stated that the explanation was clear and easy to understand and that the videos enriched the experience in the activities.

3.5. The open question: Criticism and suggestions

For the open question, "Criticisms and suggestions", we gathered 558 responses, 535 in written Portuguese and 23 filmed in BSL. Among the responses in Portuguese, 118 were not applicable or unusable and 15 were responses stating that there were no

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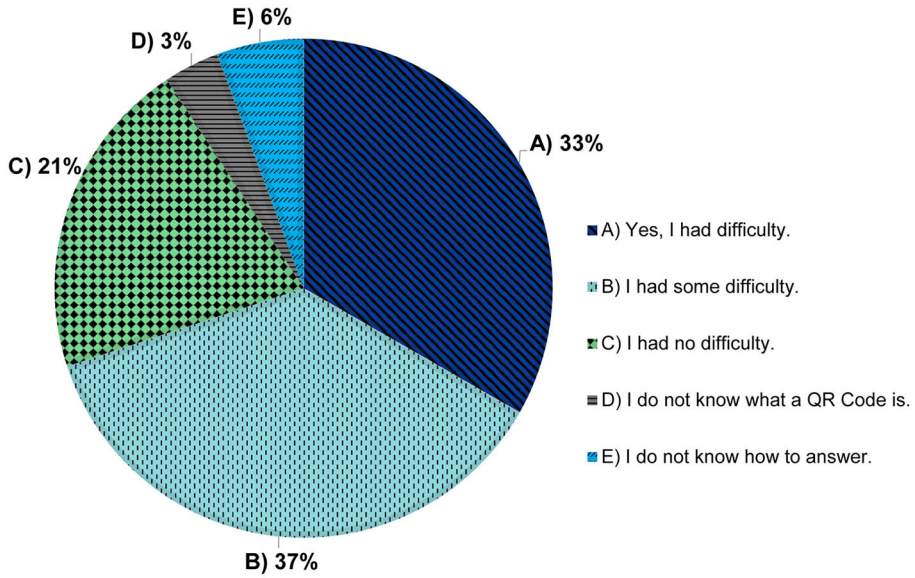

FIGURE 2
Data in percentage about the question: "Did you have difficulties accessing the activity through QR Code?" n = 745.

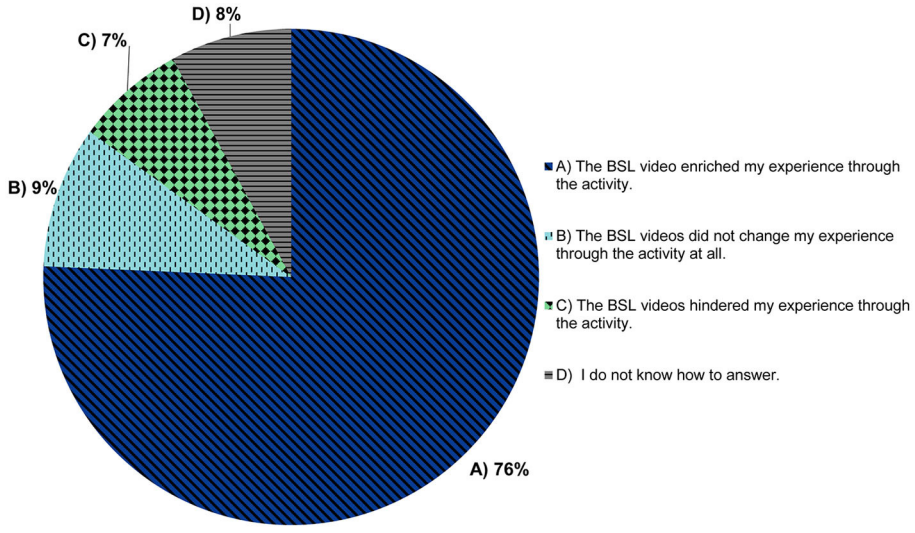

FIGURE 3
Percentual data about the video guide experience in the activities n = 745.

criticisms or suggestions. Therefore, 402 responses in written Portuguese were analyzed along with the 23 filmed in BSL.

After thematization analysis, we identified nine themes and six sub-themes:

Theme 1. "Impressions about the Experience" (356 responses) with the following sub-themes: "General Opinion" (277 responses) and "Appreciation for Different Aspects" (79 responses).

In the "General Opinion" sub-theme we gathered answers in which it was not clear what the participants liked or did not like, nor whether it was regarding the activity performed or the explanatory video. We found that, for the most part, the students enjoyed participating in the event. Many reported that they liked it, found it very good, great, wonderful, cool, that they loved it, and that it was "top". Some of them, however, reported not liking or liking it more or less.

In the "Appreciation for Different Aspects" sub-theme, we gathered responses that were specific. Some referred to the video watched (six responses), to the service (two responses), and to the activity they liked (70 responses): "Very good the video [sic]." (answer of participant "517"); "Watch the video on the tablet was different and cool [sic]." (answer of participant "3"); "I loved you guys!" (answer of participant "510"); "You all are so cool!" (answer of participant "517"); "I like 'Paper that Sprouts' is different, is cool and learning good [sic]." (answer of participant "19"); and "I

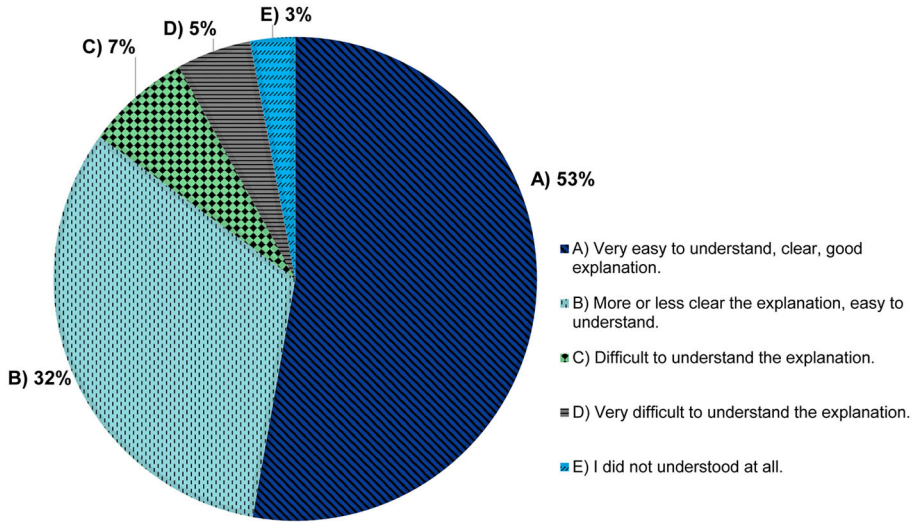

FIGURE 4
Percentual data about understanding the explanations in the video in BSL n = 745.

TABLE 1 Data in percentage about understanding the explanations in the video in BSL of each activity.

Activity	(A) Very easy to understand, clear, good explanation	(B) More or less clear the explanation, easy to understand	(C) Difficult to understand the explanation	(D) Very difficult to understand the explanation	(E) Did not understood at all
Arthropods	49%	37%	5%	4%	5%
Comparative Anatomy	51%	35%	7%	4%	3%
Discovering Microplastics	39%	41%	7%	7%	6%
Knowing your Cells	60%	32%	4%	3%	1%
Ozobot	60%	30%	5%	4%	1%
Painting the Body	53%	32%	4%	8%	3%
Paper that Sprouts	62%	26%	8%	3%	1%
Ramp	57%	28%	9%	6%	-
Secret Writing	50%	33%	9%	5%	3%
3D Printer	44%	35%	8%	8%	5%
Virtual Reality	56%	25%	11%	3%	5%

liked the robot I had to draw on the tablet. I loved it!" (answer of participant "G"). Only one participant specified that they did not appreciate the activity because they did not like to touch dead animals, "But I do not like holding dead human or rats [sic]" (answer of participant "376"), referring to the "Comparative Anatomy" activity.

Theme 2. "Attraction to the New". We identified that the different and the new attracted the interest of the participants (15 responses): "It was the first time I saw something like this, I liked it." (participant "P"'s answer); "Like 'Paper that Sprouts' is different, cool and learning good [sic]." (answer of participant "19"); "That game was cool, I have never seen it before." (answer of participant "219").

However, for some participants, there was a repulsion, due to fear or distrust of the object: "The first time he invited me to look, I was a little scared and suspicious. But as I watched, I started enjoying it, learning, increasing my knowledge, I got interested, that was wonderful !" (answer of participant "V"). Note that, at first, this participant was not attracted to the activity, but, after observing and understanding what it was about, their curiosity increased and what had previously repelled them became interesting.

Theme 3. "Interest in the Study" (nine responses). We identified interests both for the study itself and also for the science. Some students (three responses) emphasized they enjoy studying. These participants reported that it was good or very cool to study and learn through the activities. In addition, some students (six responses) said they liked the science subject or science in general: "I like the science subject." (answer of participant "I") and "...science is really cool." (response of participant "28"). This showed us that there were deaf students who were interested in science.

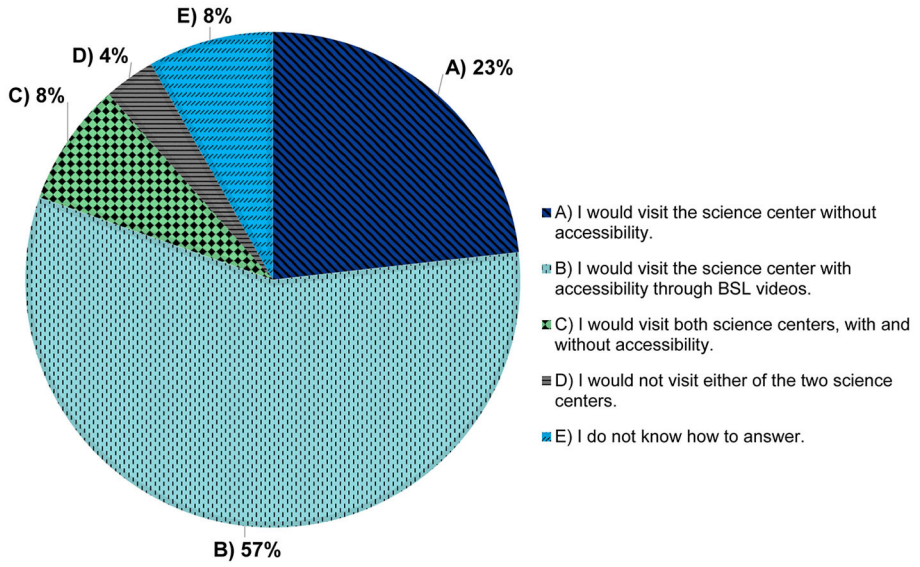

FIGURE 5
Percentual data about the question: "If there are two science centers, one with no accessibility for deaf people and another one with accessibility through video in BSL, which one would you visit?" N = 745.

Theme 4. "Description of the Activity Performed" (14 responses). Some students described the steps of the activity they performed: "Then I went there in the activity where I scraped inside the mouth, on the inside of the cheek, took the blade and put the dye, then I put it in the microscope, I had to adjust it... Then I went to the '3D Printer', I saw it printing... Then I made a drawing on the tablet and put the robot to walk…" (response from participant "W") and "I saw the different drawings wearing colored glasses, then I did my drawing also using colored glasses." (response of participant "F"). Participants who answered in BSL were the ones who most described the activities. It was interesting to observe the reproduction of the signs presented in the explanatory videos in BSL, which led us to conclude that these participants managed to retain some of the scientific-technical signs and terms.

Theme 5. "Discovery Description" (4 responses) is intrinsically related to theme 2, "Attraction to the New". Here the participants highlighted that they noticed something new, something different, and not only saw but analyzed and made new discoveries: "Then I looked on the microscope and found out how colors are made, there's blue, red, and green [sic]." (response from participant "F"). However, again in participant "L"'s response, we observed "In another activity, I saw the ramp. I tried to figure out which one came first but I was wrong. I put it on again, and I was wrong again. I put it on a third time and I could see which one came first. Why? It had a straighter ramp and I thought it would fit better, but I found it did not. And I tried it several times, put the balls on and watched. I put it back on and saw them descend. I thought it was really cool!"

Theme 6. "Understanding the Explanation in BSL" (78 responses). In total, 25 respondents found it very easy to understand, or easy to understand, 23 understood, six understood a little, one thought it was a little difficult to understand, four found it difficult to understand, and three did not understand;

Theme 7. "Valuing Information" (22 responses). In total, 14 answers regarding this theme, such as "The best accessibility information for the deaf is clear to understand [sic]" (response of participant "218") and "I thought it was good that it has accessibility and I learned about bones and other things" (response of participant "U"), were grouped together in the sub-theme "Valuing the Communication for Deaf People'. Within the sub-theme "Valuing Scientific Information", we gathered eight responses similar to participant "215", who stated: "I liked it, this is important science information [sic]."

Theme 8. "Correlations" (12 responses) – with two sub-themes: "Correlation with the Subject Studied" (seven responses) and "Correlation with Everyday Life" (five responses). After describing the activity performed, we observed that some participants related the activity to some school content. For instance, participant "297" stated, "Because make study more [sic]. Everything was 5th grade. Science, body, every name, every bone [sic]". Note that during the visit to the "Comparative Anatomy" activity, the participant, who is now in their sophomore year, was reminded of the content seen when this student was in the 5th grade of Elementary School.

Participant "A", answered in BSL and stated that "To find out about COVID-19, researchers need to look at a microscope similar to what we did when we scraped the inside of our cheeks and looked at the cell. This is how researchers investigate and discover viruses like COVID-19, which are dangerous. In the COVID-19 test, they put a swab in the nose and find out if the person is infected." This answer fits the sub-theme "Correlation with the Subject Studied" and in "Correlation with Everyday Life" because, on the days we took the activities to INES, the walls had several posters about COVID-19. This correlation could either be associated with school studies or situations experienced over the years 2020 to 2022 when the world faced the pandemic caused by the spread of the disease.

Theme 9. "Display of Emotion" (eight responses). We observed some emotional reactions to the activity performed. One student, "E", reported that they understood and felt happy. Another, "M", found the arthropods so beautiful that "M" felt emotional. A third, "R", said it was thrilling to learn from the experience.

On the other hand, there were some negative emotions, as participant "M" stated that a friend was scared and afraid to do the "Virtual Reality" and gave up on the activity. In one report, we noticed that a participant, "Q", was fearful and nervous of the scorpion in the resin; "Q" claims that they felt scared and, even nervous when taking the scorpion to observe it closely. Similarly, another student, "V", reported feeling scared and suspicious at first, but gradually, this feeling was replaced by knowledge and interest, which led "V" to say "I have learned in a playful way and that I believes [sic] I will keep this knowledge because it was wonderful and of good quality".

4. Discussion

To promote accessibility for deaf people in traveling science centers, we investigated BLS video guides. In this research, after an exhibition of CST in a special school for deaf students, it was observed that there was interest from students in carrying out the activities through such video guides. Many were curious and investigative, staying or even returning to some activities to explore the observed phenomena. It was also verified that there was a good understanding of the explanation of the videos, as revealed both in the participants' responses and in the attitude of the explainers toward their peers. On the other hand, there was a minority that had difficulties understanding the explanations and a large proportion that had difficulties accessing the videos using QR Codes. In general, we found good acceptance of the videos as a form of accessibility for deaf people who visits traveling science centers.

Most responses showed that it was easy to understand the explanatory videos; however, a minority had difficulty in understanding. One reason for that difficulty may have been due to language variations. Lang (2006) explained that, when deaf students are faced with a signaling method different from what they are used to, or with signs they are not familiar with, their understanding is impaired. As deaf people have different life trajectories, the level of BSL mastery is different for each one, as well as the way of expressing themselves (Perlin, 2016). Therefore, we consider it important to use different resources so that the information will be transmitted clearly.

In CST's videos in BSL, we decided to use more classifiers and imagery descriptions as well as inserting illustrative images. In addition, the videos had subtitles at the bottom, and whenever a term was spelled (fingerspelling - writing words with a manual alphabet), it was displayed with the capital letters in the subtitles (Ferreira, 2021a). These strategies had three goals: (a) to help the understanding of fingerspelling and some signs that may not be known by the deaf visitor, either because there is a linguistic variation or because they have never seen that signal before, especially scientific terms; (b) to diversify the way content is presented, as it is not possible to affirm that all deaf people have the same difficulty with written Portuguese or that all of them have fluency of sign language—some deaf people may find reading/writing as the best way for learning while others may better understand through images; and (c) to serve a larger audience since some deaf people do not use sign language and communicate orally using, preferably, lip reading, writing, and oralization to communicate (Perlin, 2016).

According to Vygotsky (2009), the vocabulary expansion process needs experiences that create mental representations, providing the acquisition of new abstract concepts. This allows the expansion of consciousness and changes the way people process and understand their experience in the world. However, when presenting a large amount of new and abstract information that is far from a person's reality, their understanding can be impaired. For example, microplastics are very small, and even when samples are presented, it can be difficult to understand the entire biomagnification process explained in this activity. It can be hypothesized that visitors who already understand the food chain concept will find biomagnification easier to understand. Similarly, when we talk about 3D printers, there are topics that require computational knowledge. If the visitor has had little experience in this area, perhaps the explanation that there is software responsible for "slicing" the projected image for printing is too complex. Abstract concepts are built from a set of relations. Therefore, if a visitor does not have prior knowledge to establish this relationship, the new knowledge becomes meaningless (Vygotsky et al., 2017).

The quality of the experience permeates visitor understanding and relationship with the activity. For deaf people, it is necessary to explore the visual, kinesthetic, and also reading/writing areas. Carneiro (2005) and Alencar et al. (2019) investigated cortical organization in deaf individuals and found that their visual and spatial cerebral areas were more developed. Thus, we can say that experiences that seek manipulation and interaction with the learning object as well as work in a visual way, such as using sign language and images, will contribute to a better understanding of the subject addressed for deaf students (Campello, 2007). As deaf people are diverse, some have difficulties in reading/writing Portuguese and others in using and/or understanding BLS (Campello, 2007; Perlin, 2016), the use of both sign language and Portuguese could be a better way to reach a wide audience.

During the week when the activities were being exhibited, we observed that some students who had already visited the activities returned to see, manipulate, and even watch the videos again with more attention. On the first visit, participants seemed eager to see everything and touch everything but were not so interested in the technical explanations. However, when they had the opportunity to revisit, their attitude was different, and they spent a longer time with the activities than previously and were more interested in watching the videos. Soveri (2017) states that it is important to revisit a subject so that it can be remembered. As CST cannot guarantee that the visitors will visit the same activity several times, it cannot establish learning as the objective of its actions. However, in the elaboration and application of the activities, there is a strategy so that the visitors can remember some of the experiences there or even arouse their curiosity and interest to seek more information later on. The strategies to attract and keep the visitors' attention could include: problem-solving and challenging elements, exploratory actions, hands-on activities, playful and pleasurable

activities, and positive reinforcement (Pavão and Leitão, 2007; Alves et al., 2020; An et al., 2022).

It was also observed that the activities that required the construction of something or solving a problem, such as "Paper that Sprouts", "Ozobot", and "Knowing your Cells", were the ones that participants understood more easily when compared to those activities that involved only observation and manipulation such as "Discovering Microplastics" and "3D Printer" (Table 1). Lang (2006) also found that, with the use of active teaching methodologies, such as hands-on and problem-solving strategies, there is greater participation and cognitive engagement and a better understanding of scientific content. This could be one of the reasons why, during the validation process, the group had more difficulty in understanding compared to our student participants of the research. During the validation process, the videos were watched in isolation without the practical activity (Ferreira, 2021a), while, at the research stage, the videos were watched during an in-person visit along with the interactive activity. An et al. (2022) found that there is an active construction of knowledge when individuals handle and explore a studied object, which could explain why active methodologies are easier to understand. On the other hand, the difficulty to understand some activities could be explained by a lack of prior knowledge on the subject. As observed in the research by Pereira (2021), it was identified that, among visitors from schools in Niterói city, 20% of MS students and 25% of HS students did not have any knowledge of microplastics. When investigating students from rural cities, this number grew to 51% of MS students and 35% of HS students. As the participants in our research belong to this stage of education, it is possible that the difficulty to understand some of the activities could also be explained by the lack of prior exposure to the subject. Ausubel (2003) stated that, to learn in a meaningful way, the individual establishes an interaction between previous knowledge and new knowledge. In this interaction process, prior knowledge can acquire new meanings, concepts can be expanded, or greater stability of prior knowledge can be established.

These findings of participant attitudes are consistent with the data obtained in the question "If there are two science centers, one with no accessibility for deaf people and another one with accessibility through video in BSL, which one would you visit?" in which most of the respondents chose to visit the center with accessibility through BSL videos. This positive result reveals that video guides are a resource well accepted by deaf people to provide accessibility in non-formal educational environments that do not have the resources or means to have specialized professionals to guide them on-site. However, we cannot explain for sure why some visitors chose to visit the spaces without accessibility. One possibility is that they did not understand the explanations in the videos and, therefore, would not visit places with this accessibility feature. In fact, we found that some of those visitors considered the explanations difficult, very difficult, or did not understand the explanations and felt that the videos did not change the experience in the activity or even hindered the experience. This may explain, at least for this group, their choice to visit a space with no accessibility.

In contrast, another part of those who chose to visit the space without accessibility stated that the explanations were clear and easy to understand and that the videos enriched their experience in the activities. We believe that, even understanding the explanations and having the experience enriched by the videos, the visitors probably considered watching the videos as something unwanted in an environment in which they were eager to manipulate and experience the activities. Moreover, during the event, some participants expressed that they did not like having to answer the questionnaire. Even if they understood the purpose of the research, the questionnaire could be something uncomfortable and an obstacle to exploring the activities.

Another possibility of why they chose to visit spaces without accessibility would be the difficulty that most participants had in accessing the videos through the QR Code. Although we are not sure what difficulty each visitor had, we understand that having something that hinders the flow of activity can be seen as a negative factor that influences the visitor's opinion about the experience. Perhaps, they may have struggled when the video took a while to load and, in these cases, the visitor asked the explainer for help and at times we needed to open the video directly in the Google Drive folder. Some participants had difficulties focusing on the QR Code with a tablet camera. Another possibility could be the arrangement of QR Codes, side by side, at the end of the page, as seen in Supplementary Figure 6, which made the tablet camera capture a QR Code that was not intended by the participant and often opened a video with a different background color than the one that had been chosen.

In view of what was observed, what can be done to eliminate this negative aspect is to reorganize QR Codes disposition. Therefore, the most suitable arrangement of QR Codes is one in each of the four corners of the display. Another option would be to have just one QR Code that opens a folder on Google Drive, in which all the videos with the four options of background colors are stored. Therefore, when opening the folder, it was possible to view the video image and the visitor would have been able to choose the one with the preferred background.

These data also showed us that, although video guides are an alternative for accessibility well accepted by deaf people to help them to understand the activities, the presence of an interpreter guide or a deaf visitor guide, when possible, is ideal. After all, professionals fluent in BSL, in a face to face interaction, are able to observe a deaf person level of mastery in BSL. This way those professionals can adjust their speech and use different strategies to make themselves understood.

When analyzing the open-ended question "Criticism and suggestions", we found that most students enjoyed participating in the event, as observed in theme 1 "Impressions about the Experience", sub-theme "General Opinion". However, it is not clear here exactly what aspect of the exhibition they liked or disliked or why they did. When observing the responses gathered in the sub-theme "Appreciation for Different Aspects", also in theme 1, we could identify specific references of appreciation for the service, the videos, and the activities performed. Many responses commented on the fact that they were able to understand the video and that they valued the scientific information presented to them and the way the information was presented, that is, in BSL, the language used by the deaf community, which may explain the praise for the video.

Some respondents mentioned their understanding about explanation presented in the videos in BSL, being then classified

in theme 6 "Understanding the Explanation in BSL". These data confirm the answers given in the closed question, for which the majority said was easy or very easy to understand. We believe that the adjustments made to the videos increased visitor comprehension in great proportion. In addition, the fact that they performed the activity also contributed to a better understanding. Campello (2008) cautioned that, when representing a term in BSL, the imagery strategy used to construct this concept can result in a loss of meaning. Therefore, the author warned of the need to consider the production of a symbol or of the meaning of a concept that is influenced by the person's way of reading the world around them. As deaf people have more visual perception than hearing individuals, the production of a symbol is different for each of them. Therefore, all interpreted material must be evaluated by a deaf person to verify that the expressed thought is consistent with the visual perceptions of the deaf audience. Thus, it is important to use interpretation in sign language and resort to linguistic resources for the iconic representation of the concepts presented. It is not enough to translate into a sign: it is necessary to exemplify in the body, in gesture, with the support of illustrative images so that the meaning is constructed (Campello, 2008; Fernandes et al., 2020). In addition, the experience during the activity contributed to the construction of an understanding, as it was not about watching an isolated video but more about watching it within a meaningful application. For Freire (1996) the contextualization of the taught content—here we consider this contextualization as the act of being able to interact in the activities with the science content—makes comprehension possible.

Meanwhile, when identifying the appreciation for the service, we reflect that, even with videos recorded in BSL to provide information, the role of the explainer cannot be ignored. According to studies by Carlétti and Massarani (2015, p. 2), the role of explainers is to "facilitate the visitors' experience by encouraging them to actively engage and think about the exhibition". Some CST activities require problem-solving, as in "Ozobot" in which the visitor needs to choose the correct commands and position them properly so that the robot performs the intended function. The role of the explainer is essential to lead the participants to the solution without giving the full answer but encouraging them to arrive at their answers. Even without knowing BSL, the explainers showed where the commands were and, whenever necessary, performed some examples so that visitors understood how to perform the activity. The explainer's role was also important to facilitate access to the video guides in BSL, because, as the data showed, the majority of participants had some difficulty accessing the videos through QR Code. Overall, every aspect of interaction is important and influences the visitor perception, including welcoming the participants, the explainer's facial expression showing acceptance, and searching for ways of making themselves understood so that the participants have a complete experience.

It was also observed that some participants reported the steps they performed in the activities and sometimes they used scientific terms and signs presented in the videos in BSL, as described in theme 4, "Description of the Activity Performed". Almeida and Giordan (2014) conducted a study on the speech of children aged 9 to 10 years old who had come in contact with scientific texts and observed that, after studying these texts, the children expanded their vocabulary and began to use the terms learned in their speeches to express knowledge and to build ideas. According to Melo-Dias and Silva (2019), personal experience acquires structure, meaning, and continuity through symbolization. It is also through this symbolic capacity that people communicate, understand each other, transfer knowledge, and create ideas that go beyond sensory experience. According to these authors, people have information processing skills to extract linguistic rules from their experience and knowledge and use them to encode and communicate information. The intrinsic ability to categorize abstract general features, generalize similar features, and distinguish different features of specific cases and situations provides fundamental tools for discerning regularities in language. The human thought process is based on language. Therefore, expanding vocabulary, understanding, and abstracting new concepts enables new thinking constructions in addition to expanding communication. The process of acquiring abstract knowledge permeates mastering concepts. In the scientific area, many concepts need to be abstracted for the individual to advance in the process of acquiring new content (Almeida and Giordan, 2014).

In Chomsky's generative model, creativity, including the ability of language users to form an infinite number of sentences, will be nurtured by interactions with people and the environment. When there is an input in which the information is received, there is new information in the mind, from which it is able to generate an output, that is, to elaborate several sentences (Gonçalves, 2007). Such information must be passed on to deaf people so that they can develop their potential, their reasoning, and expand their knowledge. In this way, deaf individuals can have more options to apply in their daily actions and to broaden their perspectives of professional performance or further studies. Therefore, videos in BSL may aid deaf visitors to access and appropriate abstract scientific concepts and turn them into knowledge.

It was also verified in the responses an appreciation for the use of BLS and for the care and concern in devising a way to help deaf visitors understand the activities. Fiorin (2007) pointed out that society only exists because there is communication, and communication is possible only because there is language. Reasoning, communication, imagination, and creation are possible through language. Quadros and Karnopp (2004) stated that language users have their innate psychological nature nourished in their relationships with others and improve their language skills in the same way that they increase their knowledge of the linguistic system. The presence of information in the participants' language enables understanding, contributes to the abstraction of concepts and values of the individual, showing that the space also belongs to them, and can be adjusted to their needs and, therefore, fully enjoyed.

During the visit, we were also able to observe groups of students experimenting with the "Ramp" activity and discussing what they were observing. At other times, we observed students who visited the activity and then explained or clarified their fellow students' questions, acting as explainers for their peers. We can deduce that peer collaboration and the process of building new knowledge were positive aspects of their experience in the activities. Vygotsky (1984) declared that there is the Zone of Proximal Development

(ZPD), that is, the distance between the actual level of development determined by independent problem-solving and the potential level of development determined by solving problems under adult guidance or in cooperation with an adult or competent peers. The ZPD, therefore, refers to the relevance of encouraging task-based learning that promotes development in a fundamental way in which an individual gradually acquires control and personal responsibility for problem-solving. The process of acquiring this development occurs through observation and interactive learning with others more experienced in problem-solving activities in a process of gradual internalization and self-regulation (Melo-Dias and Silva, 2019).

In addition, participants reported that they discovered something new or different, that they studied in a playful way, that they were able to perceive the presence of scientific content in their daily lives, and that the experience provoked different emotions (some good, others bad). Once again, we observed the use of active teaching methodologies during the exhibition of CST leading participants to reflect on and analyze the experiments until they were able to understand the logic and build their knowledge. According to Vygotsky (2009), the more children see, hear, and experience, the more they understand and absorb; the more elements of reality they have in their experience, the more meaningful and productive their imagination will be. The brain information-correlating activity is ultimately based on the same process by which traces of earlier arousal are preserved in it. The novelty of this function is that the brain has traces of previous arousal, and can combine them in ways not found in real experience.

Carlétti and Massarani (2015) consider that the main goal of a science communication space is to stimulate visitors' curiosity and lead them to ask questions. When participants highlight that the experience was different and that they had never seen it before, this is positive, because there is something new, and there are questions to be resolved, which generates the search for answers that can lead to learning. According to Carl Rogers (Zimring, 2010), learning something new reveals itself as a threat to the individual's previous knowledge and, therefore, there is a tendency to resist the new. When removing the barrier to accessing information and providing explanations in the students' language, we created a less threatening and welcoming environment, easing their acceptance of new information. Although CST does not aim for a learning outcome, it appears that they contribute to the participants' interest in the topics and the experiences in general, thus contributing to a better acceptance of new information regarding the content covered.

Something interesting that was observed was that some students answered that it was good or cool to study by doing the activities. Not only that, but they also emphasized that science is cool. These answers make us reflect on teaching. The fact that they were able to handle the material studied or produce something from that knowledge, reaching a concrete objective from the understanding of what is being presented, that influences the pleasure of learning. Active teaching methodologies, in which visitors are protagonists in the process of discovering and building knowledge, are stimulating, lead to reasoning, arouse interest, and make the subject significant (Bacich and Moran, 2018; Alves et al., 2020). Thus, showing deaf people what is new and encouraging them to seek more scientific knowledge is something that should be offered. According to Alves et al. (2020), science education contributes to the development of a sustainable society by enabling the dissemination of possibilities to apply innovations to create new job markets, in health areas, or even to provide greater inclusion.

In addition to discovery and novelty, the ability to establish correlations between what is being seen in the exhibition with something from life or with some studied content makes the visitor see the scientific content in a meaningful and applicable way in some area; this was verified in the responses included as theme 8, "Correlations". When individuals manage to establish these correlations, they become a protagonist in the process of the construction of knowledge. This knowledge is significant and is supported by prior knowledge. According to studies in neuroscience (Roberta et al., 2020), when a person remembers something, elaborates on it, retrieves some information in the brain, repeats it, and re-elaborates it based on new information, that person activates neurons which can promote changes in neural connections. This reorganization process is called neuroplasticity and can help register new knowledge.

Pavão and Leitão (2007) declared that one of the interactivities expected to be stimulated in science communication is minds-on. Minds-on can be defined as the ability to identify what is essential, what is different, and make associations with prior knowledge, as well as perceiving practical applications for scientific content (Pavão and Leitão, 2007; An et al., 2022). For example, interaction with anatomical pieces make it possible to remember knowledge acquired years ago. Therefore, it appears that science communication activities can contribute to remembering contents studied. It was interesting to observe how the students made associations and saw the applicability of the activity in everyday life.

One way to stimulate the consolidation of memory and learning is to tie it to something emotional. In other words, emotions are projected directly into the hippocampus, and, by involving emotion, the consolidation of knowledge is much faster (Othman and Amiruddin, 2010; Dolcos et al., 2019). With this in mind, the entire organization of CST activities, explainer training, and the creation of accessibility videos were aimed to provide a positive experience that triggers visitor emotions. The service is done with affection, attention, and care, the activities are intended to work in a playful and interactive way, and the videos are built with concern for aesthetics and the facial and body expression of the interpreter. All this care is important to provide a good environment for interest and attention to what is being presented.

Studies by Vogel and Schwabe (2016) and Dolcos et al. (2019) showed that emotion influences the process of motivation and attention of the individual. If the person is already stressed before receiving the information or if, between retrieval and updating memory, there is a peak of stress, learning does not occur. Some triggers for this stress are: having difficulty in communicating, not being understood, not understanding others, or even not feeling belonging to that environment for the simple fact that there is no accessibility there for their participation (Vogel and Schwabe, 2016; Dolcos et al., 2019). Repulsion or fear of the participants was often verified in the activities "Compared Anatomy" and "Arthropods", such as the handling of human body parts or insects, and this bothered some visitors. These reactions were also observed by Azeredo et al. (2020) when they analyzed participation in

the "Arthropods" activity. These researchers reported that many participants avoided touching the scorpion exoskeleton and even reacted with fearful expressions, which can be explained due to the stigma of scorpions being venomous, dangerous, and dirty. Carl Rogers states that a threatening environment (in this context the negative emotions) inhibits learning. Therefore, the threat must be eliminated so that the individual can learn (Zimring, 2010). By not insisting that they handle objects that cause repulsion and letting students adjust in their own time, we contributed to the reduction of this threat. In addition, providing accessibility with care and quality for deaf visitors is presented as a step to combat this threat to show deaf visitors that that environment is theirs by right, that knowledge is also for them, and that scientific research can and should be built, developed, and/or enjoyed by them.

Traveling science centers such as the CST are non-formal education spaces that present knowledge in an interactive way, seeking to stimulate curiosity and gain the interest and attention of the visitor (Alves et al., 2020). Therefore, making these spaces accessible can contribute to development opportunities for deaf people. Taken together, these data demonstrated that video guides accessible in BSL are a viable and suitable alternative for promoting accessibility in traveling science centers, especially for those who have limited financial resources and rely on the work of volunteer staff.

5. Conclusion

In view of all the above, the contribution of the guide videos in BSL as an accessibility tool for deaf individuals who visit a traveling science center such as CST was noticeable. In addition to favoring the understanding of activities and the topics addressed, they also provided, for most of the participants, greater emotional security for a transforming and pleasant experience during their visitation.

We also found that the CST's activities can make the science communication knowledge more appealing to deaf visitors because they have an interactive, dynamic, kinesthetic, and visual approach. Moreover, such activities also highlight the linguistic aspects through the use of sign language, approaching the contexts and experiences of deaf visitors and their community.

In fact, the video guides in BSL contributed to understanding and encouraged deaf people to interact with autonomy. This can provide deaf people a deeper sense of belonging, which is essential and inherent to humankind in individual and collective perception. Such understanding implies more driven perspectives and arouses the subject's attention, besides bringing curiosity as a motivator to approach scientific contents and extending them to other opportune moments of their lives.

With regard to accessing the guide videos via tablets, we found that making them available offline was satisfactory and worked well. Regarding the use of QR Codes, although intuitive, it is necessary to have codes of different colors with greater spacing between them or just a code directing to a folder with all the videos. Thus, the correct reading of the QR Code will be more guaranteed, directing the users to the video guide with their preferred background color, something that also influences their experience with the science center exhibitions.

The emotional aspect was always a concern among the entire research group, especially regarding the explainers providing a kind, friendly, and stimulating service. The positive outcome and acceptance of the experience by the visitors lead us to believe that the whole experience was far beyond just a fun experience. From our experience, it was quite memorable.

Although it cannot be said that the CST aims to have learning outcomes for deaf individuals, as this involves far more elements and issues that are not within CST's reach, it appears that the participation of deaf people in CST's activities can contribute to awakening some attention and curiosity to previously unreflected topics. It can also contribute to the deaf people's feeling of autonomy in a whole new world of possibilities, not only in scientific environment but in any environment of their choice and so giving them the role of protagonists in their own life path.

6. Limitations of the study

We identified three limitations of our study. The first one is the fact that there was only one type of questionnaire for all research participants. The participants were of different ages, different levels of education, and different levels of BSL knowledge. In an ideal scenario, all participants in this schooling group (MS and HS) would be adolescents ranging from 11 to 17 years old. In the institute where we applied the research, we observed that there was a distortion in the age-school grade relationship, in which MS and HS students ranged from 11 to 27 years old. So, we were faced with the difficulty of students of different ages being allocated to the same classes. Thereby, although the questionnaire was simple, with few questions, it depended on the self-reported perception of the participants and the fact that differences between them may influence the results. We had this concern regarding the understanding of the questionnaire, and we tried to minimize this with the presence of a researcher fluent in BSL who, in fact, at times had to help the participants in answering the questionnaire. However, in our research, a noticeable factor, regardless of the age or grade of the participants, was that the answers written in Portuguese were shorter and less elaborate, while those who felt more confident to be filmed answering in BSL presented more elaborate answers. This suggests that expressing reasoning and reporting their experiences fluidly occurred when deaf students used their preferred language, their L1. These data are aligned with what was verified by Resende (2015) who established a better identification of student development by providing a verification of learning in deaf students through the narrative in BSL. Nevertheless, thinking about attendance at a traveling science center, this wide variety of ages is something positive; after all, in a regular exhibition we do not know the exact age range of the public that will visit the activities. As a consequence, being able to analyze the opinion of people of different ages who participated in the activities by watching the video guides helps us to identify whether the format of the videos is suitable for this wide range of ages. Therefore, we suggest for further research that two or three different questionnaires be developed taking into account not only the participants' age but also the participants' knowledge of BSL.

The second limitation that we identified in our study was the absence of questions that allow us to identify more characteristics

of the participants, such as: whether they were oralized or not; whether they performed lip reading or not; whether they came from a deaf or hearing family; how long they had known and used the BSL; and how many years they had been studying at a bilingual educational institution. Data like these would make it possible to deepen the analysis of the answers obtained from the students. After all, greater knowledge of BSL or of writing Portuguese can be a factor that influences the understanding of the videos and even the contents presented in the activities. For further research, we suggest the addition of questions like those to improve the data collection.

The third limitation identified was that we did not have the means to measure the prior knowledge of the participants; after all, they were a heterogeneous group. We could not analyze what they truly understood from the theoretical content presented. However, what we could observe and discuss above was that the participants were able to interact with the proposed activities. In some cases, they established discussions about what they were observing, and, in other moments, they acted as explainers for their peers. These observed attitudes led us to believe that there was an understanding of the purpose of the activities explained in the videos in BSL. Therefore, despite the research limitation of being a self-reported answer, the fact that the participants were able to interact correctly with the activities is an indicator that they understood the explanatory videos.

Data availability statement

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

Ethics statement

This research was approved by the Fluminense Federal University's Research Ethics Committee, in accordance with Resolution nº466/12. CAAE approval number: 32464920.0.0000.5243. The participants provided their written informed consent to participate in this study. Written informed consent was obtained from the individuals and/or from their legal guardian for the publication of any potentially identifiable images or data included in this article.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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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.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/feduc.2023.1084635/full#supplementary-material

SUPPLEMENTARY FIGURE 1
Example of a folder available with QR Codes. Folder of the "Secret Writing" activity that was placed on the table. In the folder, there is a brief text with questions that introduce the activity to the visitor: "Have you ever noticed a rainbow? Why does it have those colors? Have you ever thought about how the colors of cell phone screens are formed?" At the bottom are the colored QR Codes that, when scanned, open the explanatory video in BSL with the corresponding background color.

SUPPLEMENTARY FIGURE 2
Visitor scanning the QR Code of the "3D Printer" activity.

SUPPLEMENTARY FIGURE 3
Visitor watching explanation in BSL on the tablet.

SUPPLEMENTARY FIGURE 4
Visitor performing the activity "Paper that Sprouts".

SUPPLEMENTARY FIGURE 5
"Arthropod" activity table in which the folder with the QR Code of the questionnaire can be observed, as well as the folder of the QR Codes of the "Arthropod" sit.

SUPPLEMENTARY FIGURE 6
Visitors answering the questionnaire on the tablet after performing the activity.

SUPPLEMENTARY TABLE 1
Link to each activity explained in BSL through a video with four different background options: black, white, green, and blue.

SUPPLEMENTARY TABLE 2
Table of the analysis, by Fontoura's thematization, of some of the answers to the question: "Criticisms and suggestions. You can write your answers in Portuguese below or you can record your reply in BSL. Record your answer on the camera."

SUPPLEMENTARY TABLE 3
Participants' profile: gender, age, school grade, and area/zone or municipality where each participant lives.

References

Alencar, C. D. C., Butler, B. E., and Lomber, S. G. (2019). What and how the deaf brain sees. *J Cogn Neurosci.* 31, 1091–1109. doi: 10.1162/jocn_a_01425

Almeida, S. A., and Giordan, M. (2014). A revista Ciência Hoje das Crianças no letramento escolar: a retextualização de artigos de divulgação científica. *Educ. Pesqui.* 40, 999–1014. doi: 10.1590/s1517-97022014041219

Alves, G. H. V. S., Fragel-Madeira, L., Azeredo, D., Castro, T. V., Pereira, H. C. G. R., and Coutinho-Silva, R. (2020). Low-cost scientific exhibition: a proposal to promote science education. *Creative Educ.* 11, 760–782. doi: 10.4236/ce.2020.115055

An, H., Sung, W., and Yoon, S. Y. (2022). Hands-on, minds-on, hearts-on, social-on: a collaborative maker project integrating arts in a synchronous online environment for teachers. *Leaders Educ. Train.* 66, 590–606. doi: 10.1007/s11528-022-00740-x

Ausubel, D. P. (2003). *Aquisição e Retenção de Conhecimentos. 1st Edn*. Lisboa: Plátano Edições Técnicas.

Azeredo, D. T. V., Fragel-Madeira, L., De Souza, C. M. V., Pereira, G. R., Coutinho-Silva, R., and Alves, G. H. V. S. (2020). Artrópodes e a divulgação científica: uma oportunidade para o diálogo em saúde. *Ensino Saude E Amb.* 13, 122–143. doi: 10.22409/resa2020.v13i1.a39905

Bacich, L., and Moran, J. (2018). *Metodologias Ativas Para Uma Educação Inovadora: Uma Abordagem Teórico-Prática*. Porto Alegre: Penso.

Brandão, C. R. (1999). *Repensando a Pesquisa Participante. 3th Edn*. São Paulo: Brasiliense.

Brasil (1996). *Lei de Diretrizes e Bases da Educação Nacional, LDB 9394/1996*. São Paulo: Brasil.

Campello, A. R. (2008). *Aspectos da visualidade na educação de surdos (Doctoral Thesis)*. Universidade Federal de Santa Catarina, Florianópolis, SC, Brasil.

Campello, A. R. S. (2007). Pedagogia visual / sinal na educação dos surdos. *Estudos Surdos.* 1, 100–31.

Carlétti, C., and Massarani, L. (2015). Mediadores de centros e museus de ciência: um estudo sobre quem são estes atores-chave na mediação entre a ciência e o público no brasil. *J. Sci. Commun.* 14, 1–17.

Carneiro, L. L. F. (2005). Surdez: perdas e ganhos. *Ciências Cognição* 6, 133–141.

Costa, R. M. (2021). *Surdos: Processo de Ensino-Aprendizagem na Distorção Idade-Série de Alunos Surdos do Ensino Fundamental e Médio*. São Paulo: Editora Dialética.

Dolcos, F., Katsumi, Y., Moore, M., Berggren, N., Gelder, N, Derakshan, B., et al. (2019). Neural correlates of emotion-attention interactions: From perception, learning, and memory to social cognition, individual differences, and training interventions. *Neurosci. Biobehav. Rev.* 108, 559–601. doi: 10.1016/j.neubiorev.2019.08.017

Fernandes, S., Spencer, B., and Montanha, B. (2020). Libras no museu: acesso à cultura, história e memória para os surdos. *Revista Espaço* 54, 167–183.

Ferreira, A. T. S. (2021a). Developing videos to provide accessibility to deaf visitors in itinerant science centers. *Res. Soc. Dev.* 10, e114101522440. doi: 10.33448/rsd-v10i15.22440

Ferreira, A. T. S. (2021b). II luso-brazilian seminar on scientific dissemination: strategies and reach analysis to science dissemination before and during COVID-19 pandemic. *Creative Educ.* 12, 1572–1589. doi: 10.4236/ce.2021.127119

Ferreira, A. T. S. (2021c). Libras interpretation and mediation: a post-graduate case study. *Res. Soc. Dev.* 10, e79101220196. doi: 10.33448/rsd-v10i12.20196

Ferreira, A. T. S., and Alves, G. H. V. S. (2021). A língua de sinais em museus: acessibilidade através de guias multimídias. *Interfaces Cient. Hum. Soc.* 9, 8–23. doi: 10.17564/2316-3801.2021v9n1p8-23

Fiorin, J. L. (2007). *Introdução à Linguística. 5th Edn*. São Paulo: Contexto.

Fontoura, H. A. (2011). *Analisando dados qualitativos através da tematização. Formação de Professores e Diversidades Culturais: Múltiplos Olhares em Pesquisa. Coleção Educação e Vida Nacional*. Niterói, RJ: Intertexto.

Freire, P. (1996). *Pedagogia da Autonomia: Saberes Necessários à Prática Educativa. 36th Edn*. São Paulo: Paz e Terra.

Gonçalves, R. T. (2007). *Chomsky e o Aspecto Criativo da Linguagem. Revista Virtual de Estudos da Linguagem – ReVEL*. Available online at: https://bit.ly/3xeiO4c (accessed October 17, 2022).

IBGE (2019). *Pesquisa Nacional de Saúde. Rio de Janeiro: IBGE*. Available online at: https://sidra.ibge.gov.br/Tabela/8220#resultado (accessed December 1, 2022).

Kellaghan, T. (2010). *Evaluation Research. International Encyclopedia of Education. 3rd Edn*. Amsterdam: Elsevier, 150–155.

Lang, H. G. (2006). "Teaching science," D. F. Moores, and D. S. Martin, Eds. *Deaf Learners: Developments in Curriculum and Instruction*. Washington, DC: Gallaudet University Press, 57–66. doi: 10.2307/j.ctv2rh292r.9

Lira, D., da Silva, D. S., Oliveira, A. I., Monteiro, J. P. C. J., and de Oliveira, T. A. (2021). Professor ouvinte no ensino de classificadores da Libras em escola bilíngue. *Huma. Inov.* 8, 225–243.

Medeiros Portella, S., Silva, A. F., Ferreira, L., Mendes, A. T. S., dos Santos Vale, M. C. B., de Oliveira, M. R. M., et al. (2021). As bases biológicas da surdez. *Res. Soc. Dev.* 10, e18656. doi: 10.33448/rsd-v10i10.18656

Melo-Dias, C., and Silva, D. C. F. (2019). Teoria da aprendizagem social de Bandura na formação de habilidades de conversação. *Psicol. Saúde Doenças* 20, 101–113. doi: 10.15309/19psd200108

Minayo, M. C. S. (2001). *Pesquisa Social: Teoria, Método e Criatividade*. Petrópolis: Vozes.

Oliveira, J. C. (2014). *Leitura e Escrita do Português como Segunda Língua: A Experiência de um Professor Surdo Com Um Aluno Surdo no Contexto Acadêmico'. Anais do SIELP. Uberlândia: EDUFU*. Available online at: http://www.ileel.ufu.br/anaisdosielp/wp-content/uploads/2014/11/96.pdf (accessed October 17, 2022).

Othman, N., and Amiruddin, M. H. (2010). Different perspectives of learning styles from VARK model. *Proc. Soc. Behav. Sci.* 7, 652–660. doi: 10.1016/j.sbspro.2010.10.088

Pavão, A. C., and Leitão, A. (2007). "Hands-on? Minds-on? Hearts-on? Social-on? Explainers-on?" in *Diálogos and Ciência: mediação em museus e centros de Ciência Rio de Janeiro*. L. Massarani, ed (Rio de Janeiro: Casa de Oswaldo Cruz/Fiocruz), 40–47.

Pereira, M. L. O. V. C. (2021). Public perception as an instrument of environmental education: a study on microplastics'. *Res. Soc. Dev.* 10, E45210715411. doi: 10.33448/rsd-v10i7.15411

Perlin, G. (2016). *Identidades Surdas. A Surdez: Um Olhar Sobre as Diferenças*. Porto Alegre: Mediação.

Proctor, N. (2005). *Providing Deaf and Hard-Of-Hearing Visitors With On-Demand, Independent Access To Museum Information and Interpretation Through Handheld Computers. Museums and the Web 2005: Proceedings. Toronto: Archives and Museum Informatics.* Available online at: http://www.archimuse.com/mw2005/papers/proctor/proctor.html (accessed October 5, 2020).

Quadros, R. M., and Karnopp, L. (2004). *Língua de sinais brasileira: estudos linguísticos*. Porto Alegre: ARTMED.

Resende, A. A. C. (2015). *Avaliação Pedagógica Para Alunos Surdos no Contexto de um Programa Inclusivo Bilíngue (Doctoral Thesis)*. Universidade Federal de Santa Catarina, São Carlos, SC, Brasil.

Roberta, M., Belfiore, P., and Liparoti, M. (2020). Neuroplasticity and motor learning in sport activity. *J. Phys. Educ. Sport* 318, 2354–2359. doi: 10.7752/jpes.2020.s4318

Rocha, J. N., Massarani, L., Abreu, W. V. D., and Inacio, L. G. B. (2020). Investigating accessibility in Latin American science museums and centers. *Anais da Acad. Bras. Ciências* 92, e20191156. doi: 10.1590/0001-3765202020191156

Soveri, A. (2017). Working memory training revisited: a multi-level meta-analysis of n-back training studies'. *Psychon Bull Rev*. 24, 1077–1096. doi: 10.3758/s13423-016-1217-0

Vogel, S., and Schwabe, L. (2016). Learning and memory under stress: implications for the classroom. *Nat Partner J. Sci. Learning* 1, 16011. doi: 10.1038/npjscilearn.2016.11

Vygotsky, L. (2009). *Imaginação e Criação na Infância: ensaio Psicológico - Livro Para Professores*. São Paulo: Ática.

Vygotsky, L. S. (1984). *A Formação Social da Mente*. São Paulo, Martins Fontes.

Vygotsky, L. S., Luria, A. R., and Leontiev, A. (2017). *Linguagem, Desenvolvimento e Aprendizagem. 13th Edn*. São Paulo, Ícone.

Zimring, F. (2010). *Carl Rogers*. Recife: Massangana.