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Teaching-learning Physics in Bilingual Education Schools for the Deaf

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Abstract

With the objective of investigating the challenges and contributions presented about the physics teaching-learning process in bilingual schools and special education schools for the deaf, a bibliographic review was conducted in the annals of three of the biggest national events that cover physics teaching: the National Symposium on Physics Education (SNEF), the National Meeting of Research in Science Education (ENPEC), and the Meeting on Research in Physics Teaching (EPEF). This was a qualitative study that employed content analysis to analyze the data. Only five articles were found to bring teaching-learning aspects within this context. These five articles were discussed within two emerging categories: (i) the challenges and difficulties in teaching-learning physics in a bilingual school; (ii) the actions and contributions to the teaching-learning of physics in the bilingual school. Recognizing Brazilian Sign Language (Libras) alongside bilingualism pushes the inclusion and teaching-learning process for the deaf to their full potential. In order to overcome some obstacles, including difficulties related to deaf students' literacy of the written language or educators' lack of familiarity with signs specific to physics, more significant investments are needed in the production of bilingual material, in addition to creating and spreading signs and educators' familiarity with deaf culture.

Keywords PHYSICS TEACHING • BILINGUAL EDUCATION • DEAF EDUCATION

Ensino-Aprendizagem de Física nas Escolas de Educação Bilíngues para Surdos

Resumo

Com o objetivo de investigar quais são os principais desafios e contribuições apresentadas acerca do processo de ensino-aprendizagem de Física nos contextos escolares de educação bilíngue e de educação especial para estudantes surdos, realizamos uma revisão bibliográfica nos anais de três dos maiores eventos nacionais que contemplam a área de ensino de Física: Simpósio Nacional de Ensino de Física (SNEF), Encontro Nacional de Pesquisa em Ensino de Ciências (ENPEC) e o Encontro de Pesquisa em Ensino de Física (EPEF). A pesquisa foi de cunho qualitativo, com o uso da análise de conteúdo para o tratamento dos dados. Encontramos apenas cinco trabalhos que evidenciam aspectos sobre o ensino-aprendizagem neste contexto. Discutimos esses trabalhos em duas categorias emergentes: (i) Desafios e dificuldades no ensino-aprendizagem de Física na escola bilíngue; (ii) Ações e contribuições para o ensino-aprendizagem de Física na escola bilíngue. Percebemos que o reconhecimento da Língua Brasileira de Sinais (Libras) aliada ao bilinguismo potencializa a inclusão e o processo de ensino-aprendizagem de surdos. Para superar algumas barreiras, tais como a dificuldade na alfabetização da língua escrita pelo estudante surdo e o desconhecimento pelos educadores dos sinais específicos da Física, faz-se necessário mais investimento na produção de materiais bilíngues, bem como a criação e divulgação de sinais e o conhecimento da cultura surda pelos educadores.

Palavras-chave ENSINO DE FÍSICA • EDUCAÇÃO BILÍNGUE • EDUCAÇÃO DE SURDOS

Libras, deaf culture, and bilingual education for the deaf

To contextualize this study, several theoretical assumptions of Libras and deaf culture will initially be addressed and some of the central policies that support the principles of bilingual education. Subsequently, the relationship between bilingual education and the teaching-learning process of physics for deaf students will be covered.

In the linguistic and social context, sign language is a visual-spatial language articulated by the hands and facial and body expressions; it is also formed by semantic and grammatical elements, thereby constituting the speech of deaf people[1] (Quadros & Perlin, 2007; Quadros 2008a). In this sense, Libras is a complete language and a proper element of deaf culture used by Brazilian deaf[2] communities and constituted as a linguistic right, being these people's primary mode of communication.

Culturally speaking, deafness is recognized as a difference and marked by visual experience and sociolinguistic characteristics built on the experiences of deaf subjects (Strobel, 2016). Thus, "deafness constitutes a difference to be politically recognized; it is a visual experience; deafness is a multiple or multifaceted identity and, finally, it is located within the discourse of disability" (Skliar, 1998, p. 11). Likewise, visuality is an interaction instrument between deaf subjects and the world (Skliar, 1998; Strobel, 2016). Therefore, sign language and visuality are aspects of deaf culture that are fundamentally different from listeners' cultural and social experiences.

Thus, Libras provides the development of language and thought of the deaf subject in the educational context and enables constructing technical-scientific knowledge during the teaching-learning process (Goldfeld, 1997). Therefore, Libras, visuality, and deaf culture should be privileged in deaf education because they are the main linguistic and social communication tools of these people.

Thus, we can think of bilingual education for the deaf because bilingualism considers the deaf culture and sign language as the first language, that is, as the mother tongue of deaf subjects and, subsequently, the official written language of their country — as a second language (Quadros, 2008a). Analogously, "the most important concept that bilingual philosophy brings is that deaf people form a community with their own culture and language" (Goldfeld, 1997, p.43). Hence, bilingualism can provide linguistic and cultural accessibility for deaf people.

1 Article 2 of Decree No. 5.626 (2005) specifies a deaf person as "someone who, by having hearing loss understands and interacts with the world through visual experiences, manifesting their culture mainly by use of Libras"; hearing impaired individuals are considered those with bilateral, partial or total loss, of forty-one decibels (dB) or more; measured by audiogram at the frequencies of 500, 1,000, 2,000, and 3,000 Hz. However, in the cultural context, the subjects are not differentiated by the degree of deafness within the deaf community; thus, all individuals are characterized as deaf due to belonging to the deaf culture (Strobel, 2016).

2 Deaf people and the deaf community are two important concepts about deaf culture. Deaf people encompass a group of deaf subjects who share similar histories, language, customs, or interests, but do not inhabit the same territory; they are "linked by a code of visual formation" (Strobel, 2016, p. 42). The deaf community, however, involves exchanges between these subjects in a common place where deaf people and also listeners, who uphold the same ideals about deaf culture, meet (Strobel, 2016).

> For Skliar (1997b), one of the leading bilingualism researchers in Brazil, this proposal is born in opposition to the clinical-therapeutic conception of deafness and as a political recognition of deafness as a difference. In the bilingual perspective, sign language is considered the first language of the deaf and the majority language — orally and/or written — as a second. This view on deafness and the deaf has been supported by the deaf community (Quadros, 2006, p. 51).

In this sense, "bilingual school education for the deaf, considering its discursive crossings — especially from linguistic, educational, and political domains — is considered a relevant scenario for teaching the deaf and instituted as a "truth" in deaf communities" (Müller & Karnopp, 2015, p. 2). Likewise, bilingual school education is intertwined with political factors resulting from the struggles of deaf communities and deaf movements — in search of social and educational rights — in addition, research developed in the field of linguistics and education legitimize the effectiveness of bilingualism in deaf education (Müller & Karnopp, 2015).

With this, critical political achievements have emerged, strongly influencing the inclusion of deaf people. Among the main achievements, we can highlight the recognition of Libras here in Brazil in 2002 — supported by Law No. 10.436 (2002) — and its regulation in 2005 with Decree No. 5.626 (2005).

The regulation of Libras was a political and social breakthrough, valuing the right to accessibility for deaf people — especially for educational purposes. Similarly, another right gained occurred with the regulation of Law No. 12.319/10 (2010), which ensured the presence of Libra translators and interpreters in schools. In the school environment, this professional is also known as an educational interpreter of Libras (Quadros, 2004).

Similarly, the Brazilian National Education Plan [PNE] foresees bilingual teaching-learning as a fundamental right to deaf students from 2014 to 2024, supporting bilingual literacy of deaf people and without establishing temporal terminality (PNE, 2014). Therefore, specifically in Goal 4 of the PNE, in items 4.7 and 4.13, the following is proposed:

> 4.7. Ensure the supply of bilingual education in Brazilian Sign Language (Libras) as a first language and in written Portuguese as a second language to deaf and hearing-impaired students from ages zero to seventeen in bilingual schools and classes and inclusive schools (...). 4.13. (...) ensuring the supply of teachers of specialized educational care, support, or auxiliary professionals, translators, and interpreters of Libras, interpreter-guides for the deafblind, Libras teachers, primarily deaf, and bilingual teachers (PNE, 2014, pp. 56–57).

The PNE was reinforced by the Brazilian Law of Inclusion of People with Disabilities [LBI], which also foresees bilingual teaching-learning and considers Libras as the language of instruction and as the mother tongue of the deaf. In Chapter IV, Article 28, Section IV, the LBI states that: "IV — providing bilingual education in Libras as a first language and in the written form of the Portuguese language as a second language, in bilingual schools and classes and inclusive schools" (LBI, 2015, s/p).

Furthermore, the PNE and LBI also state that, in addition to being a communication tool, Libras is a fundamental instrument for the social and educational inclusion of deaf people. Likewise, both legislations address the importance and need for investing in training and promoting and providing spaces for bilingual education (PNE, 2014; LBI, 2015). Bilingual education spaces emphasize the presence of bilingual educators immersed in the deaf language and culture and trained in various areas of knowledge. In physics education, we can define such a professional as a bilingual physics educator (Vivian, 2018).

In bilingual education, the teaching of Libras as the first language (L1) for deaf children is a necessary right to their schooling, from early childhood education until the completion of primary education, and after or simultaneously with the learning of Libras, the teaching of the official language of the country may be inserted — in its written and/or oral modality — as a second language (L2) (Quadros, 2006). Thus, it is an education based on bilingualism and prioritizes sign language and deaf culture. As for the oral language as a second language, it is essential to note that this is not a condition of bilingual education — as evidenced in the following excerpt:

> The notion that the deaf must, at all costs, try to learn the oral modality of the language in order to come as close as possible to the standard of normality is rejected by this philosophy. This does not mean that learning the oral language is not important for the deaf. On the contrary, this learning is very much desired, although it is not perceived as the only educational goal of the deaf or as a possibility to minimize the differences caused by deafness (Goldfeld, 1997, p. 43).

The written language requires higher levels of abstraction than spoken[3] language and, therefore, is a process that requires more cognitive skills from the subject. Given this scenario, for the subject to be able to appropriate and construct writing, it is necessary that he or she already has his or her mother tongue internalized because, during the psychological, social, and cognitive evolution, the external language appears before the internal one, and writing appears after the internal language, already presupposing its existence (Vygotsky, 1934). To this end, we highlight that sign language is how deaf people externalize and internalize thought. And this process of internalization and externalization is fundamental for the subsequent construction of writing.

Therefore, the delay in the internalization of language can cause social, emotional, and cognitive damage (Goldfeld, 1997), generating great difficulties in the teaching-learning process. This delay is also directly related to deaf students failing students, mainly due to a lack of access to sign language and a lengthy identification process with other deaf people (Skliar, 1998). For these reasons, deaf people must have access to Libras as L1 since their childhoods and greater contact with their cultural groups. Libras is a political, linguistic, social, and educational right. Therefore, bilingual education is relevant as "by having contact with bilingual education, the deaf completely change their opinions on school." (Dalcin, 2009, p. 55).

3 We point out that spoken language can be represented by both spoken language and sign language, and both languages are not inferior to written language; however, they require different cognitive abilities.

The immersion of deaf children in schools with bilingual perspectives is crucial in their social and educational constitution. In bilingual schools, the deaf student is welcomed, respected, and included.

> The family becomes more involved in the deaf child's education because the bilingual school proposes a dialogue between school and family in order to collectively build a relationship of knowledge exchange, identification of demands, and construction of educational proposals compatible with the reality of their students. (Dalcin, 2009, p. 56).

Consistent with this perspective, bilingual education favors Libras and deaf culture because it provides deaf students with active participation in the teaching-learning process — with the same conditions of access and permanence ensured to listener students. The teaching-learning of Libras as L1 strengthens the autonomy of the deaf in the school environment, opening spaces to include them in society. Libras is a linguistic tool and accessibility of the deaf culture and, by prioritizing this language in education, we value the deaf and show respect for their form of expression in the world. Thus, by learning the language of the deaf, we can also learn about the deaf and their culture.

In this sense, regarding educators and the role they play in the teaching-learning process of Libras for deaf students, this professional can be a listener or deaf, although he must be fluent in Libras and consider the use of methods based on visual modes in his teaching practice. These visual methods allied with Libras are fundamental to contribute to constructing meanings by the deaf student.

We also emphasize that for the performance of the teaching role, the figure of deaf educators is crucial for deaf students due to more significant experience and proximity to the language and culture of the deaf student, given that "the deaf-deaf encounter is essential to construct deaf identity" (Skliar, 1998, p. 54). In the case of hearing educators, we can also consider bilingual and intercultural education to bring both languages and cultures closer to provide communication, accessibility, and inclusion of deaf students.

As for the main challenges of bilingual education, it is important to note that bilingualism began in Brazil in the mid-nineties, making bilingual education relatively recent, and few experiences have been implemented (Quadros, 2006), requiring many political and educational confrontations. Likewise, "despite some advances in constituting proposals for bilingual school education, other challenges have arisen, especially in the field of school institutions" (Müller & Karnopp, 2015, p. 2). Given the above, the reality of the existence and implementation of bilingual schools or classes for the care of deaf students is still incipient in Brazil. Although more than 15 years have passed after the homologation of the document that recognized and regulated Libras (Law No. 10.436, 2002; Decree No. 5.626, 2005), the intensification of the advocacy for bilingual education for deaf students has only recently begun the last decade (PNE, 2014; LBI, 2015).

Moreover, "the philosophy of deaf schools, special classes, and inclusion, in general, say they should be bilingual, but work little with sign language" (Quadros, 2008b, p. 27). As we know, inclusive[4] regular schooling must also offer bilingual education in the school space for an authentic inclusion of the deaf student (LBI, 2015). Nevertheless, we recognize that inclusive regular schools are not always the best environments for the effective education of deaf students because, oftentimes, these students' educational, linguistic, and cultural rights are neglected (Vivian, 2018).

Additionally, the fact that Libras is a language regulated just over 15 years ago (Decree No. 5.626, 2005) implies many linguistic, social, cultural, and educational barriers — especially in science education for the deaf. In this path, specifically in physics teaching-learning, the linguistic barriers are due, in most cases, to the lack of conceptual mastery by the Libras interpreters, lack of knowledge of the deaf culture and Libras by educators, poor knowledge of Libras by deaf learners, and the absence of signs for scientific terminologies or the lack of knowledge of these signs (Vivian, 2018).

This leads us to reflect on the reasons to invest in physics teaching-learning. According to the National Curriculum Parameters [PCN], the teaching-learning of physics must enable the construction of a vision of physics as a tool to form a contemporary, active, and solidary citizen with tools to understand, intervene, and participate in reality. Physics should be presented as a set of skills that allow students to perceive and deal with natural and technological phenomena — both in everyday life and in the distant universe — based on the principles, laws, and models built by it (PCN, 2006). Therefore, the teaching-learning of physics in basic education — both for deaf students and listeners — can promote a scientific and technological engagement in the subjects to enable reflection and action against the social demands of their surroundings.

On this path, we can also think about the importance of teaching-learning physics in bilingual education schools. Besides the characteristics above, bilingual schools have a potential functional structure to favor the teaching-learning of physics for deaf subjects. This is because, in these contexts, most teachers and students are immersed in Libras and deaf culture — improving the approximation between sign language and scientific language.

Finally, another relevant factor to investigate the physics teaching-learning process in bilingual schools is the fact that most research and studies on physics teaching-learning focus on the context of inclusive regular schools (Vivian, 2018), which have a different profile from the context of bilingual education schools — as we have already discussed here. Thus, it is highly relevant to advance studies and research in physics

4 We understand inclusive regular schools as a space where all cultural and social differences of students are considered, respected, and welcomed, in order to provide quality education for everyone and provide specialized educational care for specific public - based on the Brazilian Constitution (1988), the Bases and Guidelines Law [LDBEN] (1996), and the Special Education Policy from the Perspective of Inclusive Education (2008). We believe that all schools should be inclusive, so suffice to appoint them as regular and/or bilingual schools. However, in this paper, we use the term inclusive school or inclusive regular school to draw attention to the theoretical and practical peculiarities that differ from the bilingual education school or special school for deaf students, as established by the LBI (2015) on the purpose of bilingual education.

teaching in the context in question. In short, we also emphasize that, for the teaching-learning process of physics in bilingual education schools, it is vital that educators have an immersion in deaf culture and Libras as principles for more efficient pedagogical care.

For these reasons, this study focuses on the teaching-learning of physics in bilingual education schools for the deaf. With the scenario presented, our objective in this study is to investigate the main challenges and contributions presented about the teaching-learning process of physics in bilingual education and special education contexts for deaf students.

To this end, we conducted a literature review of the proceedings of three major national events in the area of physics teaching, namely: the National Symposium on Physics Teaching (SNEF), the Physics Teaching Research Meeting (EPEF), and the National Meeting of Research in Science Teaching (ENPEC). Given these three events, the purpose was to draw an overview of the main challenges and contributions present in the research developed about the teaching-learning of physics in bilingual education for the deaf in the last decade, with a time frame of 2010 to 2020.

Thus, to substantiate this study, a brief discussion on the teaching-learning of physics in bilingual education will be presented, articulating some legal frameworks that guide the importance of bilingualism and intercultural approach in the school environment. Subsequently, we will outline the methodological approaches, the relations of the main aspects raised, and the results found.

Physics teaching-learning in bilingual education for the deaf

Deaf education takes place in two contexts: inclusive regular schools and bilingual education schools. In inclusive regular schools, deaf students share an environment where educators and students are listeners — in most cases. In this context, the main language in which classes are taught is the oral Portuguese language; hence, the presence of Libras interpreters must be ensured to translate and interpret school content and mediate communication between deaf and listeners in the school community (Law No. 12.319, 2010). Unfortunately, this right is not always fulfilled, which is likely because it is still a recent policy in Brazil.

The context of a bilingual school, on the other hand, foresees the organization of environments specialized in the education of the deaf. Under these circumstances, students are deaf most of the time, and classes are primarily taught in Libras — considering the use of written Portuguese language secondarily — in addition, teachers are usually bilingual and, in some cases, there is also the presence of Libras interpreters.

In general, the school has the role of forming citizens and not just providing education to students, but also by providing paths for the development of critical rationality so that these students can be socially included and perceive and reflect on social and scientific problems and situations of their surroundings (Sasseron, 2010). In this sense, the classroom is a dynamic environment in terms of the interactions between students and teachers and between these subjects and learning objects; therefore, most interactions in the classroom are mediated by language (Souza & Sasseron, 2012). Thus, social interaction is fundamental for the development of scientific language (Mortimer & Scott, 2002, 2003).

As for the role of physics teaching-learning in science education, in summary, learning science involves an appreciation of how this knowledge can be applied to social, technological, and environmental issues, as well as requiring an individual's approach to the concepts, conventions, laws, theories, principles, and ways of working with science (Mortimer & Scott, 2003). Given this scenario, the teaching-learning of physics can instigate interest, curiosity, and appreciation for science in students, contributing to science education.

The role of physics, the school environment, and the interaction process and language must be considered allies in science education for deaf students — both in inclusive school and bilingual school contexts. For this, we need to understand how deaf education occurs in these two contexts and the barriers and difficulties in the teaching-learning of physics in science education for the deaf.

In the process of teaching-learning physics in bilingual education schools for the deaf, physics classes are taught in Libras, considering the use of written Portuguese as a second language. In this scenario, the educator is a deaf or hearing professional with training in physics and must know both Libras, deaf culture, and its theoretical-conceptual field — which is scientific. In this sense, the bilingual physics educator must promote didactic interventions capable of teaching-learning physics through bilingual and visual methods. If the teacher is not bilingual, a Libras interpreter can contribute to the communication between the hearing educator and deaf student.

Unlike bilingual schools, in the physics teaching-learning process in inclusive regular schools, the educator is generally a listener, and physics classes are orally taught in Portuguese. In this space, the presence of a Libras interpreter is also ensured. Nevertheless, in most cases, in the context of inclusive regular schools, the physics educator is unaware of Libras and deaf culture; interpreters may also have difficulties interpreting scientific concepts specific to physics (Vivian, 2018). In inclusive regular schools, the greatest difficulties in science education for deaf people are found in the narratives in the classroom, which often become fragmented (Oliveira & Benite 2015). These difficulties are associated with language issues and communication between the subjects involved, namely: the physics educator, the deaf student, and the educational interpreter of Libras (Vivian, 2018).

However, even in bilingual education environments, some linguistic difficulties may still prevail, including functional illiteracy among deaf students; this is a serious consequence of social isolation that these students bring from their living spaces, namely: the different schools they may have attended, churches and, most often, their family (Santos & Freitas, 2005). Likewise, there is also a prevalence of weaknesses with the written Portuguese language by the deaf, and this weakness negatively affects the practice of the bilingual physics educator, thereby imposing a challenge in the production of discursive textual records and the understanding of scientific concepts in deaf students (Botan et al., 2013; Santos & Freitas, 2005; Silva & Kawamura, 2013; Vivas & Teixeira, 2015; Vivian, 2018).

Another barrier in the educational environment is that "even though 'special' schools claim to be bilingual, it is undeniable that most teachers still retain an oralist mentality. And (...) many have strategies based on the listening model" (Quadros, 2008a, p. 66). Hence, "a purpose of linking educational work to a concern with the cultural experience of the deaf can thereby be noted in bilingualism" (Quadros, 2006, p. 52).

Similarly, there are inconsistencies between the role of the Libras interpreter and physics teacher in the educational environment (Florentino et al., 2015; Oliveira & Benite 2015), added to inadequate training of teachers for the care of deaf students - especially in inclusive schools (Florentino, Junior, & Marques, 2015; Vivian, 2018). In the contexts of bilingual schools and inclusive regular schools, the lack of scientific signs or knowledge of these signs by educators, interpreters, and deaf students raises barriers in the mediation of scientific concepts, leading to many gaps in the teaching-learning process of physics (Vivian, 2018).

Linguistic and conceptual deficiencies are configured as barriers in the teaching-learning process of physics and educators' practice (Vivian, 2018; Vivian & Leonel, 2019). All these barriers and difficulties interfere negatively in the teaching-learning process of deaf students (Vivas & Teixeira, 2015).

With this, in the absence of scientific signs, the creation and dissemination of signs become two necessary processes because the diffusion of these signs in the deaf community is a potential ally to make science education accessible to these subjects (Passero et al., 2011; Vargas & Gobara 2013, 2015a, 2015b, 2015c).

Thus, in physics teaching-learning, we have noticed an increase in the production of works and research to create signs for scientific terminologies (Cardoso et al., 2010; Cardoso & Cicott, 2010; Cardoso & Passero, 2010; Passero et al., 2011; Vargas & Cobara, 2013; Vargas & Cobara, 2015a, 2015b, 2015c; Vivian & Leonel, 2017; Vivian, 2018). These works and studies correspond to a growing concern with science education for deaf people, contemplating promising results mainly in physics teaching-learning. This is because they present different didactic-pedagogical strategies (visual and bilingual) for the teaching-learning of physics or astronomy in deaf education as well as being an investment in the creation and dissemination of scientific signs, including possibilities to enhance the inclusion of these subjects in the educational, social, and scientific contexts. Thus, it is already possible to find numerous illustrated and sign vocabularies that have been digitally[5] spread for astronomy, mechanics, electricity, magnetism, thermodynamics, and optics.

5 The three volumes with physics vocabulary (Cardoso et al., 2010; Cardoso & Cicott, 2010; Cardoso & Passero, 2010) of the series Signaling Physics are available at the following website: https://sites.google.com/site/sinalizandoafisica/vocabularios-de-fisica. The project Signaling Physics was developed at the Federal University of Mato Grosso, University Campus of Sinop. The signs for astronomy terminologies (Vivian, 2018), on the other hand, can be accessed at the following website: https://repositorio.ufsm.br/bitstream/handle/1/15575/DIS_PPGEMEF_2018_VIVIAN_ELLEN.pdf?sequence=1&isAllowed=y, specifically in chapter VII of the document

However, we emphasize that only the creation and dissemination of signs are not enough to legitimize the scientific education of the deaf. This requires the immersion of educators in deaf culture, the technical understanding of scientific terms by interpreters, and a bilingual and intercultural approach between scientific language, Libras, and deaf students (Vivian, 2018). On this path, as already mentioned herein, understanding deaf education requires educators' recognition of Libras and deaf culture, although there are still many difficulties and barriers to overcome, especially in science education for the deaf.

Therefore, teaching-learning physics in bilingual education schools mandates a teaching practice that appropriates the knowledge of Libras and the specificities of deaf students by the physics educator — who should be bilingual (Santos & Freitas, 2005). In regular schools, there should be joint work between the physics educators and Libras interpreters to plan school activities for deaf students (Oliveira & Benite, 2015; Vivian, 2018).

Given this scenario, one possibility to overcome so many barriers and difficulties in the teaching-learning of physics includes "the need to excel when working for deaf students, starting from bilingual teaching, linked to (...) the relevance of using the students' natural language (Libras), throughout the teaching-learning process" (Menezes & Cardoso, 2011, p. 09). Consequently, in teaching-learning physics in deaf education, the pedagogical work must consider the predominant use of visuality coupled with Libras and deaf culture as links in scientific and bilingual education for the deaf (Vivian, 2018; Vivian & Leonel, 2019). Regarding bilingual teaching materials for the deaf, the use of visual resources favors the meaningful learning of these students, either through experimental activities or by using simulations (Florentino et al., 2015), as well as images, videos, among other technological resources (Vivian & Leonel 2017, 2019; Vivian 2018). These possibilities provide some of the most fruitful paths in bilingual science education for the deaf.

With this, we recognize strong indications and an emerging need to invest in deaf education with equity. For the efficiency of bilingual education, educators must know Libras. Nunes (2017) highlighted the importance of deep knowledge of Libras, and Quadros (2008a) and Strobel (2016) complemented by stating that knowledge of sign language alone is not enough; knowledge and proximity to deaf culture are crucial. As argued herein, knowing deaf language and culture is conceiving how deaf individuals understand the world and modify it (Strobel, 2016).

In the teaching-learning process of physics, knowledge about deaf culture and Libras with the support of visuality are essential factors in deaf education. This condition provides accessibility and brings deaf students closer to scientific language (Vivian, 2018; Vivian & Leonel, 2019).

Methodological Guidelines

Based on the technical procedures used, this study employed the bibliographic method. According to Gil (2002), bibliographical research is developed to investigate prepared and disseminated materials, consisting mainly of books and scientific articles. Regarding the objectives, we can classify this study as exploratory given that this type of research intends to improve ideas, explain a particular context and/or form hypotheses about a problem, usually involving a bibliographic survey (Gil, 2002).

As for the type of analysis, the investigation is configured with a qualitative approach. Qualitative analysis is organized into three stages: (i) exploration, which aims to know the aspects of the problematic situation to be investigated, including the process of collecting information; (ii) definition, the analysis is systematic and seeks to interpret the data collected; (iii) discovery, in which it is possible to concretize the verification of hypotheses and explain them based on the investigation (Lüdke & André, 1986).

Content analysis was used as a method for qualitative data analysis. This is perceived as a set of research strategies to seek meaning for the document and undergoes three stages, namely: (i) pre-analysis: the organization phase of the material used for data collection that establishes the corpus of the investigation; (ii) analytical description: the stage of deepening the material that makes up the corpus of the research, which is generally guided by the hypotheses and theoretical framework; (iii) referential interpretation: the phase of analysis, reflection, and intuition (Bardin, 2011). To analyze the data, it must first be codified, that is, by transforming the raw data of the text (via clippings and categories), which allows reaching an expression of the content (Bardin, 2011).

Therefore, to draw an overview of the main challenges and contributions present in work developed on teaching-learning physics in bilingual education for the deaf in the last decade, we conducted an empirical study through a literature review in the annals of the SNEF, ENPEC, and EPEF from 2010 to 2020. Like Lacerda et al. (2008), we believe that scientific events are an essential source in the search and obtainment of new knowledge, bringing together students and professionals from a particular area, thus enhancing the interaction between different subjects and the sharing of knowledge and practices in the area in question.

Thus, before describing the search and selection procedure of the papers, a brief presentation about the nature of the chosen events is necessary. The SNEF and the EPEF are events organized by the Brazilian Society of Physics (SBF); the SNEF, which started in the 1970s as an opportunity to address the concerns related to physics teaching at the time, has a broader character, and "it has become a tradition to present research papers, reports of teaching experiences, description of the production and use of teaching equipment, among others" (Nardi, 2005, p. 82). The EPEF only covers research on physics teaching. For Nardi (2005), it was the broad character of the SNEF that led physicists who were already only dedicating themselves to research in physics teaching to be concerned about finding a space to discuss their research projects in the strictest sense, to organize the first EPEF, 15 years after the creation of the SNEF. Nonetheless, the ENPEC is organized by the Brazilian Association of Research in Science Education (ABRAPEC) since the late 1990s; and similar to the EPEF, it only contemplates papers with research results, with the unique differential in its scope and consolidating the area of science teaching and the institutionalization of research in this area in Brazil (Nardi, 2014).

As for the time frame, this period was delimited considering that the homologation of legislation regulating deaf education has intensified in the last decade, since the regulation of the profession Libras translator and interpreter (Law No. 12.319, 2010) as well as the criteria of the PNE (2014) and the LBI (2015) as discussed herein.

Thus, we searched for papers using the search systems available on the websites of the editions of each event, except for the XIX SNEF of 2011 and all editions of the EPEF because these events do not present a search system and this required a manual search by thematic lines of the events — considering the oral communications. In the pre-analysis period (Bardin, 2011) of this study, the XXIII SNEF (2019) did not have minutes or papers published and available on the event websites.

The papers were selected by keywords, namely: deaf, hearing impaired, hearing impaired[6], deafness, deaf culture, Libras, Brazilian Sign Language, sign language, bilingual, bilingualism, and Libras interpreter. We selected the papers from this set of words that contained at least one of them in the title, keywords, or abstract. These words were chosen in order to cover the most significant number of publications in the area.

Thus, the corpus of the analysis only included the papers that contained discussions that showed the classroom contexts and practices carried out in/by bilingual education schools or special education schools in science education for the deaf — through observations, interviews, experience reports, or pedagogical actions — with specific contributions to the teaching-learning of physics. Therefore, only the papers that contained these conditions were read in full and considered in the analysis. The papers that contained the keywords used but referred to regular schools and involved theoretical research, literature review, bibliographic or documental research, as well as pedagogical actions in other areas of science education (e.g., biology, chemistry, or mathematics teaching) were excluded from the analysis process.

Results and analysis: what the papers point out

Initially, we made a general selection about scientific and physics teaching-learning for the deaf in each event using the keywords mentioned above. We found a total of 64 papers in the SNEF, ENPEC, and EPEF annals: 3 papers in XIX SNEF (2011), 9 papers in XX SNEF (2013), 5 papers in XXI SNEF (2015), 4 papers in XXII SNEF (2017), 8 papers in VIII ENPEC (2011), 4 papers in IX ENPEC (2013), 11 papers in X ENPEC (2015), 8 papers in XI ENPEC (2017), 10 papers in XII ENPEC (2019), 2 papers in XIV EPEF (2012), and 2 papers in XVIII EPEF (2020). In the other events such as XII EPEF (2010), XIII EPEF (2011), XV EPEF (2014), XVI EPEF (2016), and XVII EPEF (2018), we did not find publications with the mentioned keywords.

6 The keyword 'hearing impaired' was used to guarantee the identification of studies that still used this term, as it is already outdated according to current literature and legislation. However, the older studies still used this term.

We emphasize that not all the papers found in the general selection were part of the corpus of this review. After the general selection, we performed two more selection stages for the 64 papers found. First, we filtered all the papers that only contained approaches regarding bilingual education schools or special education for the deaf (9 papers). From these 9 papers, we filtered just the papers that specifically contained observations, interviews, experience reports, or pedagogical actions with contributions to the teaching-learning of physics in bilingual education schools or special education schools for deaf students.

Thus, only 5 papers were selected and considered for analysis. We then organized these papers by the edition of the events and ordered them alphabetically with numbering to identify them in the analysis. In addition, we presented their authorship and the schools or educational institutions involved in the investigations.

Figure 1. *Table with list of papers, authors, and institutions per event*

Event	Title	Authors	Educational Institution
XIX SNEF (2011)	(01) Gávea Planetarium: broadening the cosmological vision of deaf students	Daniel Pimenta de Menezes, Tereza Fachada L. Cardoso	National Institute of Education of the Deaf (INES) in Rio de Janeiro (RJ)
XX SNEF (2013)	(02) Physics teaching practices for deaf students in a school with a bilingual proposal	Jucivagno Francisco Cambuy Silva, Maria Regina Dobeux Kawamura	Private school for deaf students in São Paulo (SP)
XXII SNEF (2017)	(03) Conceptions of an undergraduate physics student: obstacles for the teaching-learning of hearing-impaired students	Ingrid Aparecida da Cruz, Helena Libardi	Center for Education and Support to Hearing and Visual Needs (CENAV) in Lavras (MG)
X ENPEC (2015)	(04) Analysis of the arguments produced by deaf students in an experimental activity about Dynamics	Deise Benn Pereira Vivas, Elder Sales Teixeira	Instituto Cearense de Educação de Surdos (ICES) in Fortaleza (CE)
	(05) The Appropriation of the concepts of Force and Mass by Deaf Instructors	Jaqueline Santos Vargas, Shirley Takeco Gobara	Training Center for Professionals in Education and Assistance to People with Deafblindness (CAS) in Campo Grande (MS)
Total of 5 papers belonging to the corpus			

Source: the authors (2021).

Accord the table above (Figure 1), 3 were papers published in SNEF, being 1 in XIX SNEF (2011), 1 in XX SNEF (2013), and 1 in XXII SNEF (2017); similarly, we found 2 papers in X ENPEC (2015). Thus, we found a total of 5 papers that presented discussions about teaching-learning of physics in bilingual schools or special education schools for the deaf.

In this sense, focusing on the teaching-learning processes of physics in school contexts of bilingual education or special education for deaf students and according to the very nature of the events, it is justifiable that papers with a pedagogical and school bias are published and found in the SNEF unlike the papers published in the ENPEC, which presented a more investigative and research aspect.

We also emphasize that as bilingual education for the deaf is still little explored (Quadros, 2006), few studies were found on this theme in science education — especially in the teaching-learning of physics. As a result, and possibly for this reason, we only found 3 papers in the SNEF, 2 papers in the ENPEC, and none in the EPEF until the conclusion of the present study.

In summary, out of the 64 papers, only 5 are directed explicitly to discussions involving the teaching-learning of physics in bilingual or special schools. This points to the need for investment in teaching and research on science education in bilingual education schools for the deaf, revealing the actions, role, and how the physics teaching-learning process has been developed in these training spaces. In this sense, Quadros (2008a) emphasized the importance of investments in bilingual and bicultural proposals or, according to Strobel (2016), intercultural.

Based on the objective proposed herein, as previously explained, which is to investigate the main challenges and contributions of teaching-learning physics in the school contexts of bilingual education and special education for deaf students, we directed our attention to the teaching-learning process of physics to recognize the contributions presented in the area, considering the challenges and difficulties faced and actions and strategies to overcome them in these educational spaces.

Thus, after reading the papers belonging to the corpus (Figure 1), two categories emerged for description and analysis: (i) the challenges and difficulties of teaching-learning physics in bilingual schools; (ii) the actions and contributions of teaching-learning physics in bilingual schools.

i) The challenges and difficulties of teaching-learning physics in bilingual schools: In this category, we discuss the main challenges and difficulties encountered by the authors. We noticed, in general, that the studies contemplated the linguistic deficiencies of the learners and the lack of specific signs in the area of physics as the main challenges in the scientific education of the deaf.

In paper (02), considering the scarcity of scientific signs, the authors invested in creating signs for several concepts such as inertia, gravity, electric current, and optics. This work proposed to make physics assignments accessible for high school. What is more, technologies were used for visual and multisensorial exploration, although the results revealed, with more significant recurrence, aspects about the linguistic difficulties of deaf students, especially with the written Portuguese language.

The authors of paper (02) concluded that even with the visual stimuli and predominance of Libras, the lack of mastery of the written language "implies in the non-recording of the written discourse of students about concepts in physics (...). This still constitutes a major challenge for constructing a bilingual educational model for the deaf" (Silva & Kawamura, 2013, pp. 01–07).

Study (03) involved voluntary monitoring in helping deaf high school students in physics activities in which they presented even more difficulties. The authors investigated the most significant barriers faced by students to propose solutions to these difficulties. In this investigation, one of the biggest challenges was related to solving exercises and involved several steps, as in the case of the exercises related to Newton's Laws.

Once again, the authors of study (03) observed and emphasized that linguistic and cognitive problems hinder the teaching-learning process of physics. Even though the students in the study mastered Libras, they could not consistently formalize the answers to the problems and faced challenges with the written Portuguese language. The authors also pointed out that the formalization of concepts is a difficult task and aggravated in deaf students because the language used in writing is not the natural language — the sign language. For the authors, "more and more students with disabilities are coming to high school, so it is up to us, future physics teachers (and also all the others, including in continuing education), to prepare ourselves to help all students" (Cruz & Libardi, 2017, p. 8).

In work (04), the objective was to investigate the arguments of deaf students in an experimental activity of the dynamics subject. In this case, the authors showed the difficulty of deaf students in the evolution of collectively describing information for argumentation at a conceptual level (Vivas & Teixeira, 2015).

As we can see, the absence of scientific signs and, especially, the linguistic deficiencies of deaf students are some of the problems present in science education and teaching-learning physics in the contexts of bilingual education for the deaf (Vivian & Leonel, 2017, 2019; Vivian, 2018). Weaknesses with the written Portuguese language impair the understanding and resignification of physics concepts (Botan et al., 2013; Santos & Freitas, 2005; Silva & Kawamura, 2013; Vivas & Teixeira, 2015; Vivian, 2018).

According to Vygotsky (1934), acquiring a written language is a process of greater complexity and abstraction and requires a high degree of articulation between the signs and meanings so that the subject can re-signify the thought, the external language and, subsequently, the internal language. Similarly, due to the linguistic deprivation of most deaf people, the delay in language construction hinders cognitive processes (Goldfeld, 1997), substantially interfering with the learning of scientific concepts. In addition, scientific knowledge requires more abstract thinking to understand laws and concepts; therefore, social interaction is essential in the teaching-learning process of physics (Mortimer & Scott, 2002, 2003; Souza & Sasseron, 2012).

The authors of paper (04) reported the problems with producing written Portuguese language to the late learning of the mother tongue, Libras. As we have already discussed, it is only after learning Libras that learning the written Portuguese language happens — according to the proposal of bilingual education — (Quadros, 2006, 2008a). Hence, the deaf student may face many losses in the written Portuguese language by being deprived of Libras. Moreover, in work (04), the authors also stated that some educators were unaware of the culture and language of deaf students, constituting an aggravating factor in the teaching-learning process.

> We can cite the teachers' lack of commitment to the need for an appropriate method for the visuospatial specificity of the deaf: the physics teachers' classes are exclusively expository, and they claim the lack of a laboratory for the lack of experiments or any other activity that uses visual factors as the main tool to provide the learning of scientific concepts (Vivas & Teixeira, 2015, p. 7).

In bilingual education, recognizing the deaf language and culture is fundamental in the teaching-learning process (Nunes, 2017; Quadros, 2008a; Strobel, 2016). This recognition brings the educator and student closer together and brings the student closer to their linguistic identity and scientific concepts (Vivian, 2018). Quadros (2008b) stated that it is necessary to evidence what deaf subjects think and how they are situated in society.

On this path, we recognize that it is necessary to understand deafness and the language of the deaf through the deaf themselves, so we need proximity with deaf individuals. "The main issue for bilingualism is Deafness and not deafness, that is, studies are concerned with understanding the Deaf, their particularities, their language (the sign language), their culture, and the unique way of thinking, acting etc. and not only the biological aspects" (Goldfeld, 1997, p. 43).

Given this scenario, following the discussions raised so far and recognizing the challenges to be faced, it is pivotal to reflect on the role of bilingual education in the teaching-learning of physics. Thus, physics educators concerned with the scientific education of deaf students must consider bilingualism. This concern requires a bilingual and intercultural approach between the teacher, deaf student, and Libras interpreter. This approach is essential for recognizing cultural and linguistic peculiarities that guide deafness, minimize distances, and enable the inclusion of deaf students in the teaching-learning process of physics.

ii) The actions and contributions of teaching-learning physics in bilingual schools: we observed that the creation of signs and use of technological and visual resources for the conceptual articulation of physics were the main actions presented in the papers to overcome challenges as possible forms of overcoming the difficulties and contribute to the teaching-learning of physics in bilingual education of deaf students. In addition, teaching autonomy in bilingual schools and the strengthening of deaf culture and Libras are potential tools in promoting the teaching-learning of physics for deaf students.

In paper (02), the authors pointed out that there was more interest from the students when creating signs and explaining the concepts in sign language. As for the educators' practice, the authors reported that "images are used to explore aspects of science in general and projects to present videos and images while always asking students what they understood from that image" (Silva & Kawamura, 2013, p. 5). The authors also highlighted the potential of the bilingual school for student autonomy and the distinct performance of educators who use visual methods in their teaching practice.

As previously discussed, visuality is how the deaf understands the world, and this is a crucial factor in pedagogical activities in the teaching-learning of physics for deaf students (Vivian & Leonel, 2017, 2019; Vivian, 2018). Likewise, the authors noted recognition of the peculiarities of the students because "in the evaluations, teachers consider the time and problems of understanding in Portuguese so as not to harm in the understanding of the conceptual issues of physics" (Silva & Kawamura, 2013, pp. 5–6).

Similarly, paper (03) showed that using pictures, drawings, objects, details of the exercise, and slow reading of physics activities favored deaf students in understanding and solving the exercises. Thus, we realize that an approach between visual bilingual teaching practice and deaf culture is possible, and this proximity may be promising for deaf students to better grasp scientific concepts.

Skliar (1998) stated that: "the visual potentialities and capacities of the deaf cannot be understood only concerning the linguistic system that is proper to sign language. Deafness is a visual experience" (p. 27). Thus, there is no doubt that visuality is the primary means for exploring scientific concepts by the deaf student during physics teaching-learning. Physics in bilingual science education should be grounded in the visual representation of concepts by using pedagogical and/or technological teaching resources.

In this sense, we understand that the physics pedagogical practices in bilingual schools are and/or should be related to Libras and deaf culture, that is, with the visual way the deaf think, act, and communicate. Bilingual schools include the deaf as they consider the difference an ally throughout the teaching-learning process.

> Being deaf, being a listener, feeling foreign, being there and here, seeing others as exotic or perceiving oneself as exotic, and being on the border are some of the inclusion processes. Thinking about deaf education requires ongoing negotiation in school spaces. There is no way to simplify inclusion because the complexity of differences is part of day-to-day education. It is indeed possible to have bilingual education, although this requires a focus on all these elements to bring the deaf difference to the school and make it a space of bilingual construction. The coexistence of languages in these spaces, the presence of translators and interpreters of sign language, the deaf as actors of education. An education with deaf people and other deaf people with other listeners. Thus, we begin to negotiate a possible education for the deaf, regardless of the spaces (Quadros, 2008b, p. 13).

The main role of the school is to provide an environment of critical education (Sasseron, 2010). Thus, the primary intention of physics teaching-learning in science education for deaf people is to provide means to include them in the scientific context, providing access to this knowledge and forming critical citizens.

In paper (01), an investigation was developed with INES students in a non-formal space and a trip to the Gávea Planetarium for the teaching-learning of astronomy. The students were guided by a teacher and a deaf educational assistant. The authors pointed out that they considered the students' prior knowledge and an oral and written assessment as tools. The study involved several astronomy topics and approaches on aspects of the evolution of scientific models and the implications of astronomy in culture and human life throughout human history.

> And by understanding that scientific dissemination must be extended to everyone, the Fundação Planetário da Gávea, managed by the Rio de Janeiro City Hall, develops a project for deaf students to watch a special movie session inside its dome. Thanks to a state-of-the-art optical planetarium, the sessions are held and fully narrated in Libras.(Menezes & Cardoso, 2011, pp. 07–09).

The intention of work (01) was to promote inclusion in the scientific environment and contribute to a more solid construction of knowledge in physics. In this study, visual experiments were explored; "the dome session was very instructive and helped a lot for the notion of the size of the universe (...) the teacher verified that some students had knowledge of Newton's Laws and Kepler's Third Law" (Menezes & Cardoso, 2011, pp. 7–9).

As we have seen in the papers reported thus far, there have been many efforts among physics educators and Libras interpreters or instructors in providing and ensuring that deaf students can understand physics and its social implications. "It is important to include the proper dimension of physics and science in the appropriation of contemporary culture spaces" (Menezes & Cardoso, 2011, p. 7).

Furthermore, we also highlight that the use of visual and technological teaching resources are potential allies in the teaching-learning of physics for the deaf, because in deaf education, "all mechanisms of information processing, and all ways of understanding the universe around them, are built as visual experiences" (Skliar, 1998 p. 28). Thus, it is necessary to invest in visuality and the construction of visual and bilingual teaching materials in science education for the deaf.

> There is a need to do distinct work for deaf students from a bilingual education, which implies recognizing deafness as a difference and not as a disability and the relevance of using their natural language, Libras, throughout the teaching-learning process (Menezes & Cardoso, 2011, p. 9).

The study (05) presented the notions of deaf instructors about the concepts of force and mass. Interpreters and a listener of the Libras course of the Deaf Service Center participated in this study, and the authors showed that these instructors initially showed an everyday conception of the concepts, although they showed a conceptual evolution in arguments and problem-solving via interactive interventions. The authors consider that interactive classes with digital resources favor visualizing physical phenomena by the deaf, contributing to the interactions and mediations, especially when there are no scientific signs. This work reveals the importance of investing in the continued education and training of deaf education professionals.

> In the instructors' arguments, we observed that the concepts of force and mass were evolving as they were used in the problem-solving situations in which the application of these concepts was requested. We credit this result to the concern in planning and executing the interactive classes by using means that bring the deaf closer to the phenomena and also to the fact that the interpreters who mediated the translation during the classes were also able to clarify their doubts about physics concepts, translating them correctly. (Vargas & Gobara, 2015, p. 8).

In the teaching-learning of physics in science and bilingual education for deaf students, professionals and educators must be immersed in sign language, deaf culture, and scientific language (Vivian, 2018). Thus, by ensuring conditions of access and equity, we build pathways for deaf learners to engage with science and interfere in society critically.

In addition, we can highlight the potential role that bilingual schools play in the educational life and scientific education of deaf students because these schools are integrated mainly by professionals committed to deaf culture and sign language. In addition, bilingual schools enable the experience of the deaf among deaf collectives, legitimizing the deaf experiences.

> With the implementation of bilingual schools, the deaf began to be heard and their language and culture recognized, enabling them to access subjects in their language. As a result, they now master the fundamentals of scientific knowledge, understand how society works, have resources to tell their story, and be subjects of history. They go from being spoken to and being told to speaking about themselves and their culture. They become citizens capable of creating new perspectives and alternative and equally effective ways of realizing the human condition, enabling the appropriation of all human aspects, both biological and psychological (Dalcin, 2009, p. 55).

With this, and articulating the information in the PCNs (2006), PNE (2014), and LBI (2015) regarding the importance of Libras in science education for deaf students, we emphasize that "bilingualism, when well used and added to all the stimulations that the deaf can have, provides equal conditions for learning and development of these students compared to hearing students" (Menezes & Cardoso, 2011, p. 9).

In short, according to the objective adopted in this study, reinforcing: to draw an overview of the main challenges and contributions present herein about the teaching-learning of physics in bilingual education for the deaf, we recognize the linguistic shortcomings concerning the difficulties of students with the written Portuguese language, the lack of scientific signs, and in some cases a distance of educators regarding Libras and deaf culture as main the challenges. Nonetheless, we noticed educators' efforts to invest in actions to overcome these difficulties. The main actions adopted involved using visual and bilingual pedagogical strategies through didactic and/or technological resources adapted to the educational, linguistic, and cultural context of deaf students.

Based on the analyzed studies, we understand that the bilingual school environment is characterized as a productive space for investing in strategies closer to the cultural and linguistic experiences of deaf students, also favoring a contextualized teaching practice more consistent with the reality of these students. Thus, the school of bilingual education is constituted as a favorable environment to provide scientific education for the deaf; we realize that recognizing the challenges, teaching actions, and potential of the school of bilingual education for the deaf as the main contributions to the teaching-learning of physics for deaf students established in research in this last decade. In addition, the results obtained within the panorama presented here contribute to shedding more light on the physics teaching-learning process for deaf subjects and the search for strategies to meet the challenges and search to ensure the inclusion and permanence of these subjects in school. Lastly, bilingual education in physics provides linguistic, social, educational, and scientific access, which is of utmost importance for deaf students.

Final considerations

Regulating Libras and instituting bilingual education for the deaf are historically recent and political achievements marked by struggles and deaf movements. The political and educational advances in bilingual education have shown promise in linguistic accessibility for the deaf. Similarly, we realize that recognizing Libras and deaf culture combined with bilingualism has positively influenced the teaching-learning process of the deaf. Thus, if bilingual education is still recent and few experiences have been implemented — still requiring many political and educational confrontations — even more recent are the investigations and studies that deal with this education in physics teaching, thereby reinforcing the relevance of this study.

In the teaching-learning process of physics for the deaf, there are still numerous barriers to be overcome. These barriers are mainly related to the difficulty with the written Portuguese language by the deaf student, a distance of the deaf student with Libras — among other linguistic shortcomings — the absence of scientific signs, the lack of knowledge of scientific signs by Libras interpreters, teachers, and deaf students, as well as the lack of knowledge of Libras and deaf culture by the teacher. Therefore, bilingual education is of utmost importance for these subjects.

Thus, the knowledge built with the investigations in the school context of bilingual education has much potential to contribute to the accessibility and approach of deaf students with the scientific language through pedagogical strategies that dialogue with the deaf culture and the use of didactic and visual and/or bilingual technological resources. Moreover, we understand that this research on the work developed within the teaching-learning of physics in bilingual education schools for the deaf enabled recognizing the challenges, the teaching actions implemented, and the reality of this context. This recognition is essential for developing new practices and deepening future research in the area, constituting one of the main contributions presented both for the teaching-learning of physics for deaf students as for research in the scientific education of the deaf, reaffirming the importance of this study.

With this, it is vital to invest in the production of bilingual and visual resources and teaching materials and the creation and dissemination of specific signs of physics. Equally, the knowledge of the natural language of the deaf and deaf culture by educators working in science education for the deaf is fundamental. Another relevant factor is that bilingual schools consider the family's active role in the learning of the deaf student in view of comprehensive education. Bilingual schools also have more effective pedagogical resources in deaf education because they value the deaf identity, the language of the deaf.

As we can see, recognizing the peculiarities of the deaf together with a visual pedagogical practice favors a bilingual and intercultural approach. This approach strengthens the relationships between the deaf learner and the specific physics concepts and enhances the scientific teaching-learning process by deaf students.

Thus, we can consider that the formation and training of bilingual teachers and Libras interpreters, investment in creating signs, and bilingual visual teaching resources can significantly advance scientific knowledge in deaf education. When we think about educational equity and inclusion of deaf people in the educational, scientific, and social environment, these are possible means to be strengthened.

Finally, we can conclude that there are still few approaches that illustrate the scenario of physics teaching-learning in bilingual education schools, making it is necessary to intensify work with investigations and research involving the teaching-learning of physics in bilingual education for the deaf. It is substantially important to recognize the reality of these spaces to strengthen the teaching-learning process of bilingual physics in science education for the deaf.

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No potential conflict of interest was reported by the authors.

Compliance with Ethical Standards

The authors declare this study was conducted following ethical principles.