DOI: http://doi.org/10.5007/2175-7941.2024.e91392

Inclusive Education Unit: A proposal for physics education for deaf high school students[*]

Lucas Teixeira Picanço[1]
Amazonas State Secretary of Education
Agostinho Serrano de Andrade Neto[1]
Marlise Geller[1]
Lutheran University of Brazil
Canoas – RS

Abstract

The Inclusive Education Unit (IEU) is a didactic sequence created to teach physics to deaf students, which is the subject of this article. The teaching approach expands the concepts of a Potentially Significant Teaching Units (PSTU) by emphasizing the development of pedagogical strategies that deem the cultural identity of deaf students. The ITU's creation process is described, highlighting the activities developed within it. At the end of the day, the results of applying this approach are presented in the context of a special school for the deaf in Rio Grande do Sul during the Covid-19 pandemic. As the main finding, it is emphasized that the participants of this research had a limited concept of the energy theme before the pedagogical intervention, restricting it to electrical energy. Still, when the teaching and learning process is finalized, they began to recognize, albeit partially, other forms of energy and they created signs to name two of the most explored forms of energy in the didactic sequence. Finally, the successful aspects are highlighted, and those that can be improved, as well as some possibilities of this methodology application to other topics of the curricular component of Physics and different contexts of special education, highlighting the possibility of building new ITU, such as the presented in this article.

[+] Unidade de Ensino Inclusiva: Uma proposta de Ensino de Física para estudantes surdos do Ensino Médio

[*] *Recebido: October 14, 2022.*
Aceito: July 30, 2024.

[1] E-mails: lucas.t.picanco@gmail.com; agostinho.serrano@ulbra.br; marlise.geller@ulbra.br

Keywords: Special Education; Education of the Deaf; Teaching Physics; Potentially Significant Teaching Units – PSTU; Inclusive Education Unit – IEU.

I. Introduction

According to Zabala's ideas (1998), it is one of the fundamental goals for any good professional, and even more for the teacher, to be increasingly competent in their job. This is an eternal search for the Greek ideal of praxis, a practice grounded in theory or conscious awareness.

From this perspective, considering the teaching and learning process, Zabala (1998) leads us to ask: (a) How can educational practices be improved? (b) Which experiences, models, examples, and proposals are most or least suitable for implementation in the classroom? (c) What criteria should be used to evaluate them? (d) Can the results obtained by other researchers in other educational contexts be applied to our context, either fully or partially? (e) Are the empirical results sufficient to justify using a particular learning theory or methodology? (f) Do these results apply to all students regardless of their starting point, without considering the conditions in which we are and the means at our disposal?

Certainly, the answers to these questions are not trivial. They are, just like everything in the educational environment, filled with great complexity. There are multiple factors that need to be considered, such as the educational context itself.

Zabala (1998) states that the educational context is a microsystem that consists of a specific space, social organization, and interactive relationships. The system's integration of didactic resources and educational processes results in a direct impact on pedagogical interventions. Despite the complexity of the most diverse educational contexts, which has been highlighted by many authors (e.g., Schwartzman; Brock; Neves; Kassar, 2005, 2007), have reported that educational practices can be revisited and improved in a number of aspects.

The main focus of this article is on enhancing educational practices in the teaching of Physics in a special education environment for deaf students. The proposal was a didactic sequence developed for a PhD research project in the Graduate Program in Teaching of Sciences and Mathematics at the *Univesidade Luterana do Brasl* (ULBRA). It is approved by the Ethics Committee under Protocol Number CAAE: 26499019.8.0000.5349, which consists of what is called the Inclusive Education Unit (IEU).

This concept is original and contributes to Moreira (2011)'s ideas on Potentially Significant Teaching Units (PSTU). Regarding the development of strategies for adapting and creating didactic sequences for deaf students, it is important to first respect their cultural identity and provide viable teaching strategies relevant to their cognitive development.

In section 2, it is presented what PSTU are and how they have been utilized as a teaching methodology in diverse educational contexts, across diverse areas of knowledge. It also presented the theoretical framework used in the construction of this didactic sequence, the Cognitive Mediation Networks Theory (CMNT) (Souza, 2004), and the reason it was chosen.

Section 3 specifies the references, making it converge to the specific content of this work, teaching the topic of Mechanical Energy, modulated in our IEU. We provided a description of all the activities we devised in our theoretical framework for CMNT (Souza, 2004), levels of physical manifestation (Gabel, 1993) and principles of deaf education (Campello, 2008; Quadros, 2006).

The didactic sequence application proposed for deaf students in their first year of high school in a school for deaf students in the state network of Rio Grande do Sul was analyzed and the results are presented in Section 4. In section 5, there is a presentation of extensions to the IEU, considering other inclusive contexts. The final points are about the progress of construction and the evaluation of the IEU presented.

II. Potentially Significant Teaching Units (PSTU) and the Cognitive Mediation Networks Theory (CMNT)

According to Moreira (2011), PSTU is a didactic sequence based on learning theories, particularly those related to meaningful learning. This definition given by Moreira complements the definition of the didactic sequence highlighted by Zabala (1998, p.). 20), in light of the fact that didactic sequences “are a way to chain and articulate the different activities along a didactic unit”.

In different educational contexts, many authors have used didactic sequences or specifically PSTU, either in the teaching of Portuguese language, mathematics, biology, and chemistry, among other curricular components. But in the teaching of physics, most of the use of PSTU as a methodology for the teaching of mechanics, optics, wave, electromagnetism, atomic models, and quantum physics is in the teaching of physics (Picanço, 2022a, cap. 2).

However, despite the relevant work highlighted by Picanço (2022a) in these areas of knowledge, it is observed that the literature becomes scarce, with regard to strategies development to adapt at and/ or creat Teaching Units (or even Didactic Sequences) for deaf students in Physics Teaching. In this research, we found few articles (Vargas; Gobara, 2015; Picanço; Cabral Neto, 2017; Morales; De Carvalho; Philippsen, 2020) that explore this teaching methodology for the deaf, emphasizing that there is a wide path to be taken.

Based on Moreira's (2011) assumption that a learning theory should support PSTU, we chose CMNT as our theoretical foundation, following Freitas's (2019) models. However, considering representation levels of physical phenomena (Gabel, 1993) and the principles of Special Education for Deaf in Physics Teaching (Picanço, Andrade Neto, Geller, 2021). Also, looking at their cultural identity and its specific characteristics (Quadros, 2006; Campello, 2008); and the use of digital resources of Assistive Technology (AT), as Hypercultural mediators (Picanço; Andrade Neto; Geller, 2022b).

The CMNT is a recent theory proposed by Bruno Campello de Souza in his doctoral thesis (Souza, 2004). This theory integrates many essential aspects of the main already established Cognitive Theories, such as the Genetic Epistemology of Jean Piaget, the Conceptual Fields Theory of Gérard Vergnaud, the Lev S. Vygotsky's Learning Social Theory, and Robert J. Sternberg's Intelligence Triarchic Theory. CMNT is relevant to our deaf teaching physics context because it offers a current approach, seeking to explain the Digital Age impacts and the introduction of Information and Communication Technologies (ICT), in society and in the individual cognitive structures of human beings (Souza, 2004; Souza *et al*., 2012).

Thus, the choice for the CMNT (Souza, 2004), instead of the Meaningful Learning Theory (MLT) as theoretical reference for IEU, is justified by the fact that both theories are cognitivist. To put it differently, they concentrate on the way the connoisseur interacts with the knowable object, maintaining convergent points. In addition, CMNT offers a contemporary approach to how we interact with digital technologies, describing that human cognition is not limited to brain function but extends beyond it. This occurs because we complement this function with auxiliary and external processing to the brain, which includes objects, artifacts, social groups, and cultures (Souza, 2004).

By drawing a parallel between these two learning theories, we can also observe many similarities. Starting, for example, from the subsumption process in IEU (AUSUBEL, 2003), we see that this is contemplated in CMNT through the activation of 'drivers' in the individual's brain processing (Souza *et al*., 2012). For Souza and collaborators (2012), these drives are mental representations of a basic system or code composed of 'theorems in action' as defined by Vergnaud (1997 *apud Souza et al*., 2012).

That is, while the IEU says that for the student to learn in a meaningful and non-mechanical way, he needs to anchor the new concept to a previous knowledge, through a potential learning object or a prior organizer (Ausubel, 2003). The process of CMNT is accomplished by connecting the object of knowledge with the driver of information processing through cognitive mediations (Souza *et al*., 2012). The gestures of students recalling interactions with simulators can be evidence of this process (Trevisan; Andrade Neto, 2014; Freitas; Andrade Neto, 2019; Trevisan; Andrade Neto, 2019).

The most important aspect that led us to choose CMNT is not the similarities between these two theories, but rather the most relevant one. Souza's (2004) Theory establishes that the process of building human cognition involves four types of cognitive mediation: Psychophysical, Social, Cultural, and Hypercultural, which make it a descriptive model for human cognition.

Picanço, Andrade Neto, and Geller (2022b) present examples of these mediations collected in literature, many of which apply to the education of deaf people. Authors especially highlight the use of digital resources for AT for the deaf, presenting a classification for these resources based on the ideas of Esquembre (2002). Although, we do not seek to discuss the details of CMNT, but rather to use it as a beacon, to offer as a suggestion that pedagogical proposals for the deaf can be based on these four cognitive mediations. Specially on Hypercultural mediation, also in view of the context of remote and/or hybrid teaching, recently experienced with the Covid-19 pandemic in the teaching of the deaf (Picanço; Andrade Neto; Geller, 2023).

Therefore, knowing that psychophysical mediation is constituted through the human being's interaction with a physical object, such as an abacus, for example, in our proposal, it occurs in the execution of physical experiments (laboratory or home), and social one happens in the dynamic interaction between research participants (in person or remotely). While cultural mediation is established through the analysis of videos of human activities, such as the practice of sports.

In our teaching proposal, greater emphasis is placed on Hypercultural mediation, which is more evident in the realization of activities in which technological resources are more prominent and in the implementation of digital AT resources described by the authors Picanço; Andrade Neto and Geller (2022b).

The materials listed here focus on didactic resources that emphasize the visual-spatial dimension of deaf culture, in accordance with Visual Pedagogy (Campello, 2008). Our CMNT reference (Souza, 2004; Souza *et al*., 2012) is in line with these materials.

In the following section, we present our IEU, which outlines all the activities developed within it, in accordance with our theoretical framework.

III. The construction of an Inclusive Education Unit (IEU)

During the IEU building process, in addition to the CMNT theoretical framework (Souza, 2004; Souza *et al*. 2012), presented in the previous section, we sought to meet the specific needs of deaf students, from a simple questionnaire or text, which is made available in digital format and has the aid of a Brazilian Sign Language (BSL) translation plugin, to the use of Augmented Reality (AR), to ensure that translation of the functioning of a physical or virtual experiment.

We also developed or adapted AT resources for the implementation of IEU, which we understand, within our theoretical framework, as hyper cultural cognitive mediators (Picanço; Andrade Neto; Geller, 2022b). We tried to check whether there was a translation of physical concepts into BSL, by consulting, for example, its dictionary on the platform of the National Institute for the Education of the Deaf (NIED) and, if so, to check that there was no conceptual misunderstanding; and, if not, we used classifiers[2], adopted a glossary or developed signs for translation with the deaf community researched.

Therefore, the Teaching Unit was structured to allow the teacher to analyze and implement these resources according to their pedagogical possibilities and needs. These are the

[2] In Sign Language, classifiers are morphosyntactic structures, characterized by configurations of hands and body parts, which are used in verbs of movement and location, as articulators to indicate the name of the referent or the agent of the action (Bernadino, 2012).

elements to improve their practice, especially to tutoring deaf students, as they help to explore the visual characteristics of experiments, simulators, videos, applications, or software when teaching physics to the deaf. That is Visual Pedagogy, which favor pedagogical methods and teaching materials that rely on visual support (Campello, 2008).

However, we don't want to cause epistemological obstacles and inappropriate visions for the models of physical phenomena (Mortimer, 2000), giving too much prestige to one aspect over another. The approach adopted in this IEU aims to provide an education that evidence the three levels of a physical phenomenon representation (Gabel, 1993). This approach was used in chemistry teaching (for hearing students) by Carobin and Andrade Neto (2003) and Perry and Andrade Neto (2005), who extended Gabel's (1993) ideas and adopted three levels of representation for natural phenomena, namely the sensory, the symbolic (equations, tables) and the physical model (microscopic or not) levels.

In our pedagogical proposal, the sensory level is presented in experimental activities, while the symbolic one is represented by analytical approach, concepts, equations, tables, graphs, and the BSL that are needed to explain the phenomenon. The physical model level can be seen in computer simulations. These levels are described in the following subsections, all of which are worked on together throughout the IEU, in varying degrees of epistemological depth.

We have computer modeling (hyper cultural cognitive mediation) to exemplify given content at a higher level of abstraction and with visual resources. In addition to Information and Communication Technologies (ICTs), such as smartphones and computers, which are also used as tools for AT digital resources. Bearing in mind the National Common Curriculum Base (Brasil, 2020) normative guidelines, this IEU proposes a set of activities, methods and materials that can be explored in the 1st year of high school, in the thematic axis Matter and Energy, with the theme principles of energy conservation, worked over 7 lessons, as shown in the following subsections.

IV. Description of planned activities

Lesson 1: Analyzing students' prior knowledge.

Lesson 1 aimed to ascertain the students' prior knowledge by means of a diagnostic test. This step was important for establishing a relationship between the content that will be studied in the next lessons of the Inclusive Teaching Unit and the students' daily lives. The lesson began by encouraging the students to express their prior knowledge about energy. To did this, each student received a questionnaire with open-ended questions such as “what is energy”, “what types of energy can you identify in the figures below” etc. The students' answers were important as they established the level of individual and class understanding before the pedagogical intervention, they were fundamental to continue implementing the other planned lessons, and they served as a “measuring scale” when new questionnaires were applied throughout the IEU.

Based on the students' answers, the teacher was able to classify them according to their knowledge level of the topic, developing and/or applying some kind of taxonomy that indicated the student's level of understanding, for example (e.g., PICANÇO, 2015). Students should try to answer the questions individually without exchanging information with each other, and the teacher should restrain himself from answering the questions, so that the students try to think about the proposed topic and present their initial ideas about it.

Lesson 2: What do you understand about ENERGY?

Lesson 2 intended to socialize students' prior knowledge verified in the diagnostic test through a debate (social cognitive mediation). This step was basic for establishing a dynamic relationship between participants' daily lives and the content that will be studied in the next IEU lessons. After collecting the questionnaires, the teacher scheduled the meeting (in person or online) with the students and asked, for example: what types of energy do the images represent? How important is the study of energy for people, science, technology, and society? The teacher asked directly and specifically to each student, or he asked all at the same time and any student was free to answer, that was done to avoid embarrassment.

Lesson 3: What is energy anyway?

At this stage of IEU implementation, it is introduced some concepts about abstract ideas that represent energy concepts in different contexts, some of the main forms of kinetic and potential energy, energy transformation, the principle of energy conservation and the Work-Energy Theorem (Halliday; Resnick; Walker, 2016; Hewitt, 2015; Yamamoto; Fuke, 2016), respecting the symbolic representation level, presented in an expository and dialogued lesson (social cognitive mediation).

Using Datashow (in person) or Virtual Learning Environment (VLE) (synchronous or asynchronous), the teacher presented mechanical energy main topics and principal forms, such as gravitational potential energy, kinetic energy, and elastic potential energy, highlighting the most fundamental principles of nature, the principle of energy conservation, and the work and energy theorem.

Lesson 4: Experimental activity: the transformation of energy.

Energy transformation is a major phenomenon in nature. To understand it, it is important to know how and why work is done, in the physical sense of the term (the product of a force acting in the direction of the motion, by the distance traveled by a body) (Hewitt, 2015). Thus, divided into smaller groups, the students conducted two experimental activities, which correspond in our methodological approach to the macroscopic representation of the phenomenon, i.e., it corresponds to the sensory level (Gabel, 1993) and to psychophysical cognitive mediation (Souza, 2004).

In the first experimental activity, they used a toy car attached to a pulley and to a counterweight to transform gravitational potential energy into kinetic energy, as shown in Figure 1. In the second one, students conducted a conventional free falling experiment, dropping a rubber ball, and modeling clay balls.

Fig. 1 - Setting up the experimental activity "Fun physics cart".

With these simple experiments, students observed, in practice, how potential energy is transformed into kinetic energy. To conduct these activities, the students received a script to perform each task, and they should answer a few questions about the phenomenon of taking footage with the smartphone camera, using the VidAnalysis-free app (hyper cultural cognitive mediation), similar to what Moraes (2019) has done.

This stage of data collection with the smartphone is the key for operationalization and mathematical modelling in the next lessons. Using the app, students established the instantaneous velocity at specific points during the rubber ball fall, for example, and lately determined the kinetic and potential energy and applied the conservation of energy principle.

Lesson 5: Analyzing Energy in two daily examples: the skate park and the circus.

Knowing how to recognize and classify the different forms of energy is important to identify principles and laws governing motions, as it is linked to daily lives, since students can understand human activities (cultural cognitive mediation) such as the practice of sports, like skateboarding, or even recreational activities, like jumping on a trampoline. This lesson started by recapping some of the points from the previous one, especially those relating to energy transformations. After this review, students were asked how the concepts presented in the previous lesson apply to our daily lives.

To raise awareness and to encourage students to understand and contextualize the knowledge presented in the previous lessons, they were shown two videos (with subtitles and BSL translation) and a report on the 24 m high Mega Ramp, built by skateboarder Bob Burnquist. The first one was a video clip from a *Globo Esporte* report showing a wheelchair user challenging the mega ramp, and the second was also a video clip but from Cirque de Soleil's "Ovo" performance.

In small groups or individually, the students made two simulations, "Energy on the Skateboard" (PhET Colorado) and "Trapeze Artist Energy" (LabVirtual - USP) or Scratch (Animation developed by the authors), available for free on internet. These educational objects are simple, and their use can be intuitive, but to make interaction easy and objective for simulations, an activity roadmap was drawn up to help students solve questions and problem-situations.

Therefore, this lesson explored the level of the physical model representation, using both simulators to demonstrate how the scientific model can be applied to daily activities, highlighting the energy forms that engage in the process and the energy transformations.

Lesson 6: Computational modeling and math tools that translate the principle of energy conservation.

Up to this lesson, the phenomena studied were approached empirically and conceptually, based on principles and direct observations of a physical experiment or simulation. It was treated without the appropriate mathematical formalism, which is part of its quantitative description. During this lesson, students learnt the analytical approach based on the classical equation of the principle of mechanical energy conservation (Halliday; Resnick; Walker, 2016; Hewitt, 2015; Yamamoto; Fuke, 2016). So synesthesia between the three levels of the phenomenon representation: sense, symbolic and modeling levels will be evidenced for deaf students (Picanço; Andrade Neto; Geller, 2021).

To this end, the equation of gravitational potential energy, the equation of kinetic energy and the principle of energy conservation are presented, applied to the problem-situations exemplified in the execution of the "Trapeze Artist Energy" simulation during lesson 5, and in the data from *VidAnalysis-free* Video Analyzer application, collected in lesson 4.

This lesson was a decisive step in the formal consolidation of the content because students should learn how to use the equations that are of fundamental importance in solving questions and problem-situations related to external assessments and entrance exams, which are part of content operationalization. It began by recapping some issues from Lesson 5, especially student notes during the activity guide, about the kinetic, potential, and total (mechanical) energies presented in the "Trapeze Artist Energy" simulation. After this brief, students were asked how these values are determined and how they could find these values using math modeling.

Since the students were familiar with the concepts, principles and the phenomena, Lesson 6 presented the analytical form of the activities developed in the previous lessons. The lesson started with a mathematical analysis of data collected in lesson 5. Point by point, students calculated kinetic and gravitational potential energy and conservation of energy, as requested in the activity guide for lesson 5, considering the trapeze artist's height (h), speed (s) and mass

(m) in different situations. Increasing math analysis difficulty level, the students applied their knowledge in the real world, by analyzing the data from the *VidAnalysis-free* application, collected in lesson 4.

Students needed to be perceptive, as they had to use equipment (such as a scale, stopwatch and measuring tape) to determine the height (h), speed (s) and mass (m) of the rubber ball, and then calculate the kinetic and the gravitational potential energy and the conservation of energy. The students used the *Modellus* (or *Scratch*) *software*, following Wolff (2015), to check and validate the developed calculations from previous activity.

To facilitate interaction and ensure greater convenience, students received a file with a math model to be used in the *Modellus* (or *Scratch*) *software*. All they had to do was use the records adopted in the previous activity for the height (h), velocity (v) and mass (m) of the rubber ball, and then check if calculations for kinetic and gravitational potential energy and the conservation of energy, carried out previously, are correct or are following the theoretical prediction, even if there are numerical differences (due to the acceleration value of gravity in the location, imprecision in measuring lengths, air resistance etc.).

Lesson 7: Final diagnostic test.

This last lesson of the IEU was intended for applying a final diagnostic test, to formally verify changes in the students' understanding level or signs of learning in relation to the first test, regarding the concepts of gravitational potential energy, kinetic energy, the conservation of mechanical energy principle, and the work-energy theorem. Students also had the opportunity to solve problems about the conceptual and analytical approach, and to observe the information provided in the questions, jointing with their knowledge.

To do this, the students answered a test with six open-ended questions, but more targeted than the questions in the initial diagnostic test. This lesson was intended to lead the student to provide a more complete answer, going beyond the given information to derive a more general principle. This concludes the description of our IEU, and the following section presents some results with the performance of a group of deaf students from a special school.

V. Results: Student performance and evaluation of the Inclusive Education Unit

Due to the inherent characteristics of special education for the deaf, as well as the gradual adherence of students after school activities return during the pandemic, the total of participants in this research was six, identified throughout the article as “students A01, A02, A03, A04, A05, and A06”.

To enrich the participants analysis, some author`s notes were considered (Quadros, 2006; Perlin, 1998, 2002, 2014; Thoma, 2009) in relation to how deaf people understand deafness and themselves in the process of self-affirmation, and to how these individuals’ conceptions can impact on their posture and behavior. According to Perlin (1998; 2002; 2014), there are seven deaf subjects’ identities: (a) deaf identity (political identity); (b) hybrid identity;

(c) floating identity; (d) embarrassed identity; (e) transitional identity; (f) diasporic identity; and (g) intermediate identity. For this context, deaf and floating identity stand out.

Deaf identity is strongly marked by the political positioning of being deaf, a culturally defined subject different from the listener, something that is seen in five of the six participants. However, as far as identity is concerned, as Perlin (2002) points out, student A06 calls attention because she has a fluctuating identity: she always uses speech to answer questions, oralizing the answer, sometimes signaling, sometimes not. Throughout the activities listed in the teaching proposal, she used onomatopoeia to explain certain phenomena, something that was not observed in the other deaf students.

The study was developed in this unique universe, with peculiar and fascinating characteristics. We chose to realize a qualitative analysis (Minayo, 2013), since it os intended to answer particular questions, referring to Special Education, the deaf education; using interpretative descriptive analysis as a theoretical reference, we sought to understand the process IEU development and application through a "[....] kind of 'open guideline' for empirical research", suggested by Rosenthal (2018, p. 12).

To begin this analysis description, we point out that seven lessons were originally planned for the IEU, but the teaching sequence ended up with 11 lessons, four more than what was planned. In addition, during some lessons, due to a combination of factors, we fortuitously had two class periods available, as shown in Chart 1.

Chart 1 – Classes distribution

Class	**Concepts covered**	**Activities undertaken**
Lesson 1 1 Lesson Time	Students' prior knowledge	Initial diagnostic test - Part 1
Lesson 2 1 Lesson Time	Students' prior knowledge	Initial diagnostic test - Part 2
Lesson 3 2 Lessons Time	Socialization of the recorded answers in the Initial Test	Debate
Lesson 4 1 Lesson Time	Conceptual introduction to kinetic and gravitational potential energy	Dialogue lecture
Lesson 5 2 Lessons Time	Energy transformation processes	Carrying out physical experiments
Lesson 6 1 Lesson Time	BSL for kinetic and gravitational potential energy	The creation of signs for Kinetic energy and Gravitational potential energy
Lesson 7 2 Lessons Time	Mathematical formalization of the content: equations for Kinetic, Gravitational Potential and Elastic Potential energy	Dialogued lecture
Lesson 8 1 Lesson Time	Mechanical energy conservation principle	Dialogued lecture

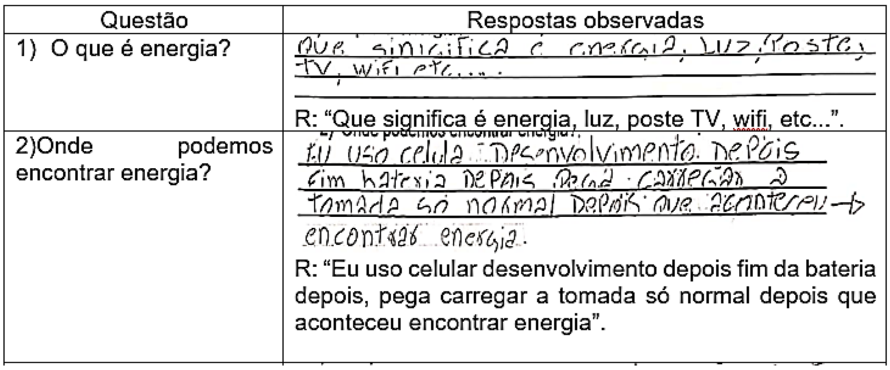
Lesson 9 **2 Lessons Time**	Transformation of energy in daily examples	Energy simulation on the skate park
Lesson 10 **2 Lessons Time**	Transformation of energy in daily examples	Energy simulation on the trampoline.
Lesson 11 **Lessons Time**	Learning evidence	Final diagnostic test

Extending number of classes occurred due to the initial research findings, which led to an adjustment in the original approach, to provide better reception to the six participants of this research. The following subsections highlight these findings.

V.1 Students' prior knowledge on energy subject

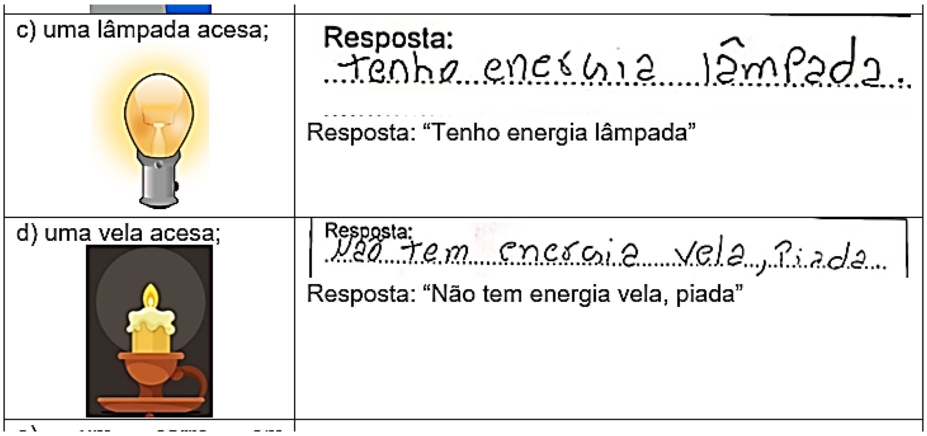
One of the main findings concerns the students' prior knowledge on the subject of energy. The first part of the initial diagnostic test has five questions: 1) What is energy? 2) Where can we find energy? 3) In what everyday activities do you use energy? 4) Can an object have energy? and 5) When is energy important?

In the second part, each student must analyze a series of images, identifying whether or not there was energy in the situation described in it, justifying their answer. Eight images were presented with the following situations: (a) kicking a soccer ball; (b) climbing a mountain; (c) a light bulb being lit; (d) a candle being lit; (e) a car in motion; (f) riding a bicycle; (g) a rocket launch; and (h) the sun illuminating a city. The following pictures show some of the records.



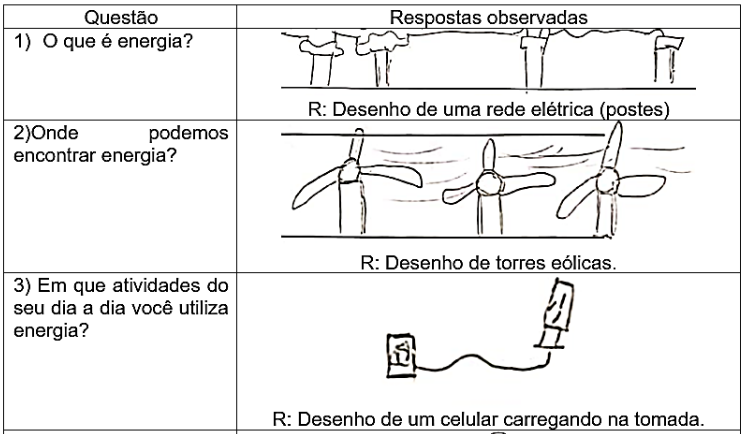
Questão	Respostas observadas
1) O que é energia?	R: "Que significa é energia, luz, poste TV, wifi, etc...".
2)Onde podemos encontrar energia?	R: "Eu uso celular desenvolvimento depois fim da bateria depois, pega carregar a tomada só normal depois que aconteceu encontrar energia".

Fig. 2 - Student A01's answers to questions 1 and 2 of the initial diagnostic test.



c) uma lâmpada acesa;	Resposta: Resposta: "Tenho energia lâmpada"
d) uma vela acesa;	Resposta: Resposta: "Não tem energia vela, piada"

Fig. 3 - Student A01's answers to items "c" and "d" of question 6 of the initial diagnostic test.



Questão	Respostas observadas
1) O que é energia?	R: Desenho de uma rede elétrica (postes)
2)Onde podemos encontrar energia?	R: Desenho de torres eólicas.
3) Em que atividades do seu dia a dia você utiliza energia?	R: Desenho de um celular carregando na tomada.

Fig. 4 - Student A03's answers to questions 1, 2 and 3 of the initial diagnostic test.

For the reader who is not used to the written response of a deaf student, the responses highlighted in the previous figures may be strange, they may even seem tautological; however, we emphasize that they must be disconnected from the hearing norm, and that we must look at them differently (Thoma, 2009).

In this section we interpret these answers and not necessarily their literal meaning, considering the whole process, the translation from BSL to Portuguese, the students' ideas before and during the written record, and the video recordings of the students' answers explanations. This means that the students' answers were restricted to electrical energy, whether writing or drawing, all of them mentioned this form of energy, either directly or indirectly.

For example, in the first part of the diagnostic test, student A03, who only used drawings to express his thoughts, when asked what energy is (question 1) and where we can find energy (question 2), drew a picture of an electricity grid and a wind farm, respectively, thus highlighting the distribution and production of electricity. And not only that: he pointed out that he uses electricity to charge his cell phone (question 3), that poles and wind turbines have energy (question 4) and that it is needed at home (question 5). Similarly, student A02 also answered the first four questions with drawings? an electricity distribution network (question 1), an air-conditioning unit (question 2), a fan (question 3), a socket (question 4) and also pointed out that electricity is dangerous (question 5).

It's interesting to note that all students mentioned this form of energy more than once and, given that we are surrounded by several electronic devices and household appliances, this form of energy is one of the most evident in our daily lives. This influenced all the students' answers, as student A01's answer to question 4, when she said that the light bulb (Figure 5, incandescent bulb above the door, on the right-hand side of the image) for the time switch is an example of an object that can contain energy.

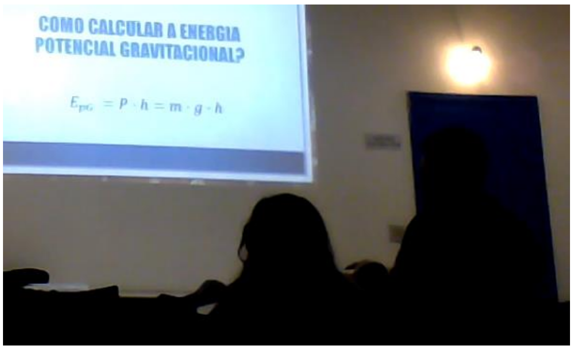


Fig. 5 - Signal lamp.

It is important to stress that the sign for energy in BSL originally refers to electrical energy, and not to other forms of energy, this may have influenced their responses, perhaps corroborating the hypothesis raised by Roald and Mikalsen (2000) that the forms of the signs that represent objects can affect deaf people's conceptions and that their visual/spatial language can have implications for how they are constructing their view of the world.

Analyzing the answers given by students A01, A04 and A05 to the second part of the diagnostic test, we can notice the predominance of an energy concept strictly linked to electrical energy. For example, student A01 was sometimes categorical in stating that there is no energy in a candle, and that this was a joke (question 6 - d), or even that she doesn't know, from her own experience, which riding a bicycle has energy (question 6 - f). These show that she is referring to the electrical energy concept, which is not present, or not evident in these two situations, but there are other forms of energy involved (namely, chemical potential energy in the wax of the candle and in the muscles, thermal, luminous, and kinetic energy etc.).

The same is highlighted in student A04`s answers, who states that there is no energy in a candle because there is only fire (disregarding it is a form of energy, thermal energy), and in student A05`s answer, who replies that he thinks there is no energy in a candle (question 6 -

d) and that it is “clear that there is no energy” when referring to the sun (question 6 - h). Some answers, both in the first and second parts of the diagnostic test, also provide a broader view of energy, but all of them are imbued with common sense, and not necessarily with technical scientific terms from Physics, such as associating the concept of energy with that of physical disposition or vigor in the human body.

This is the case, for instance, with regard to student A01's responses to questions 3, 5 and 6-a, and student A05's responses to questions 3, 5, 6-a and 6-b, which implicitly acknowledge the necessity of energy for bodily movement. The biological processes of synapses and ATP in muscles highlight chemical potential energy, as an example. Student A04's answers to questions 6-e and 6-f showed that energy is associated with feelings such as happiness.

Based on the students' responses to the initial diagnostic test, we made some changes to the IEU, and the responses served as a starting point for modifying concepts in the classes that followed the initial diagnostic test, thus allowing the students to know or recognize other forms of energy, more specifically mechanical, gravitational potential, elastic and kinetic energy, that is stressed in the final diagnostic test answers, as shown in the following subsection.

V.2 (Re)knowledge of other forms of energy

Based on the teacher's advice in this research, we decided to retake the initial diagnostic test, as he stated it would serve as a clear distinction between the pre- and post-intervention phases. Out of the six students enrolled in the class, three participated in the last lesson of the IEU. Students A01 and A05 completed the initial and final tests, while student A02 finished only the first part of the initial test and the entire final test.

It is possible to verify a clear change between the initial and final answers:

A) They began to consider other forms of energy besides electricity.

B) They were able to identify, albeit partially, which energies are present in the situations listed in the tests.

The following pictures show some of the students' answers to the final diagnostic test.

Questão	Respostas observadas
1) O que é energia?	que significa é energia cinética, energia Potencial gravitacional, energia Potencial, energia Mecânica, energia térmica. R: “Que significa é energia cinética, energia potencial gravitacional, energia potencial, energia mecânica, energia térmica”.

Fig. 6 - Student A01's answers to questions 1 and 2 of the final diagnostic test.

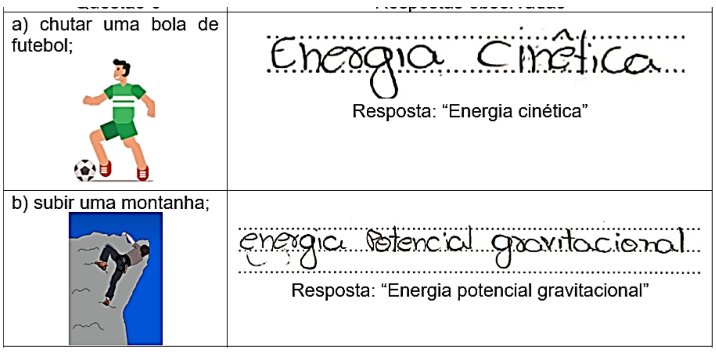


Fig. 7 - Student A05's answers to items “a” and “b” of question 6 of the final diagnostic test.

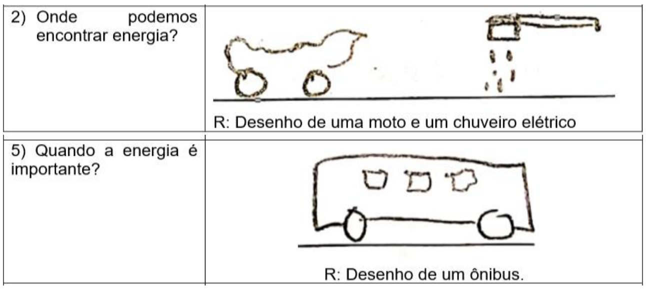


Fig. 8 - Student A02's answers to questions 2 and 5 of the final diagnostic test.

Analyzing student A01's answers, we observe that she now recognizes all the types of energy discussed during the IEU lessons (question 1). She has also advanced further by identifying these energies in various processes, such as the kinetic energy of the winds in rain (question 2) and potential energy in a soccer match (question 3), while still acknowledging electrical energy (question 5). Additionally, she partially identified the key energies illustrated in question 6. It's noteworthy that in the pre-test, she thought that asking if there was energy in a lit candle “was a joke.”

The same analysis applies to student A05. His answer to question 2 is particularly noteworthy, as he mentions different forms of energy and correctly relates the state of motion of his body to kinetic energy (questions 3 and 5) and cold (absence of heat) to thermal energy (question 4). This was not specifically addressed in the IEU but demonstrates an expanded understanding in the way he analyzes this household appliance.

Last but not least is student A02, who has an Individual Study Plan (ISP) due to a mild intellectual disability, found it difficult to perform calculations during the lessons and was also the one who participated the least. However, differences in his initial and final tests indicate that he has learned the concepts. It is important to highlight that during the final test, this student would ask the teacher participating in the research (in BSL) to confirm his answers. For example, he asked, “The car is moving, so it's kinetic energy?” or “The lamp, the candle, the sun are hot, so it's thermal energy?” The teacher would always explain that the answer was his own and that he couldn't say yes or no.

This shows that, despite the economy of words when writing, he understood the concepts covered. Even in the questions where he used drawings, a change is noticeable. For example, in question 2, he draws a motorcycle and an electric shower as objects that have or can have some form of energy. He also illustrates with a drawing of a bus that energy is important in this means of transportation (question 5) (Figure 8). We believe that these students show signs of learning the concepts and we can observe that the intervention was successful.

V.3 The creation of signs for the terms “Kinetic Energy” and “Gravitational Potential Energy”

Our results are not limited to two tests, the initial and the final; in fact, we would like to stress the entire process developed during the IEU application, as our records of each lesson provided observations that we found remarkably interesting and that could provide topics for future researches. For sure, we can highlight the process of creating two signs, spontaneously by the students, so that they wouldn't use dactylology for the terms “kinetic energy” and “gravitational potential energy”.

The students agreed among themselves that the “kinetic energy” sign would have the same movement as the energy sign used in BSL (commonly associated with electrical energy), but with a different hand configuration, where the dominant hand is in the configuration of the letter “E” and the secondary hand in the configuration of the letter “C” and moves in a horizontal zigzag movement, as shown in the Figure 9.

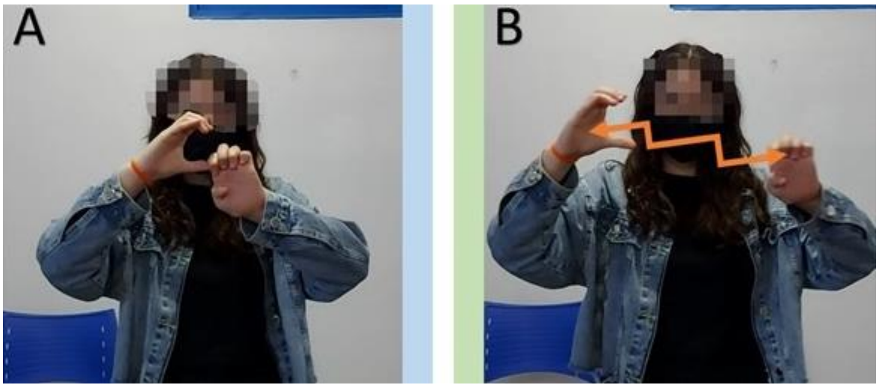


Fig. 9 - Student A06 making the Kinetic Energy sign.

The sign for “gravitational potential energy” is iconic and distinct from the previous one. The students selected a unique hand configuration, with the secondary hand forming the shape of the letter “E” and the dominant hand positioned at the end of the secondary hand in the shape of the letter “P”. From this position, an arc is made over the secondary hand, ending in the shape of the letter “G”, as illustrated in Figure 10.

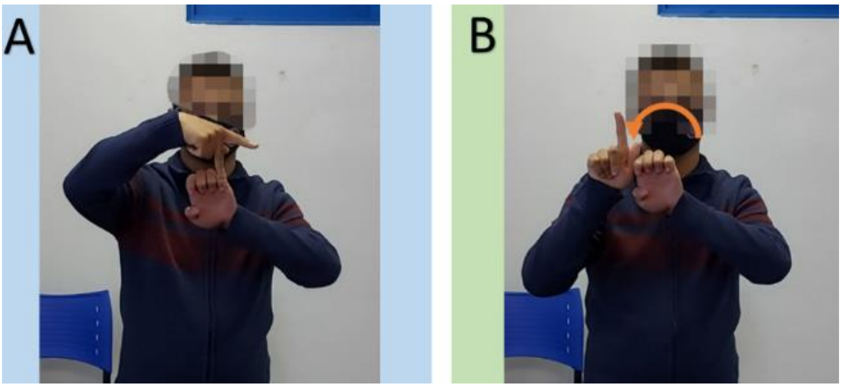


Fig. 10 - Student A05 making the Gravitational Potential Energy sign.

It is possible to observe linguistic borrowings from the Portuguese language in these signs, but when asked, participants said that using the initial letters of the words made it easier to remember the concept. We emphasize that we did not interfere in the creation of these signs (they are spontaneous from the students) and until that moment they had not been introduced to the nomenclature used in the scientific language of Physics. It adopts the letter E with the letters P and G in the subscript of the index for gravitational potential energy. Therefore, the sign emerged naturally, and this whole process was described by Picanço in his doctoral thesis (2022a), highlighting deaf students' "speeches" with their understand about the concepts, and the signs created confirm this.

We would like to highlight that the use of these signs is limited to this specific context, and the decision not to use classifiers to describe them was made by both the teacher and the students. The study of these signs is particularly intriguing from a semiotic perspective (Vygotsky, 2004), and further research is needed. For instance, the configuration of the "Gravitational Potential Energy" sign suggests the concept of a gravitational field, which may indicate that the students have grasped the concepts discussed in the IEU lessons.

IV.4 The use of hyper cultural mediators

Lastly, one of our key findings was the use of hyper cultural mediators, with the cell phone being the most prominent. This was something we didn't initially anticipate in our planning, but it turned out to be a pleasant surprise. We observed that students consistently used their smartphone's text editor to record their answers when they did not ask the teacher how to spell a word. This behavior illustrates the additional cognitive processing described by Souza (2004) and Souza *et al*. (2012). These authors noted that deaf students use this tool to enhance their writing in Portuguese, thereby freeing up working memory (Sweller, 2003) to focus on their understanding of physical concepts.

In addition to using cell phones, we also utilized simulators, which proved to be highly productive. The students interacted with the software and generated their own observations and explanations, which intrigued the researchers. This was exemplified by the PhET Colorado simulation on energy in the skate park. Figure 11 shows student A05 engaging with the simulation.

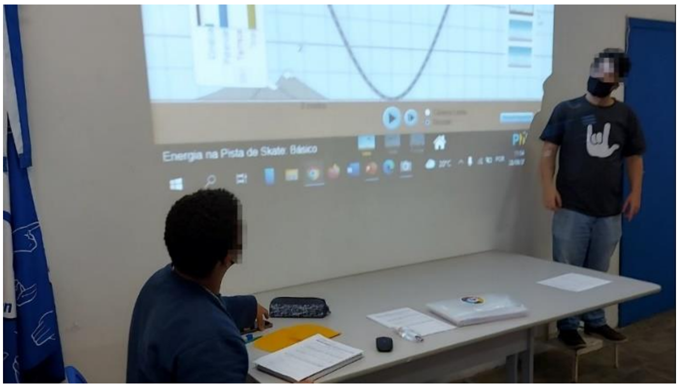


Fig. 11 - Student A05 interacting with the "Energy on the Skateboard" simulation.

Another highlight was the use of videos that enabled us to observe phenomena aspects not visible to the "naked eye", such as the deformation of a ball upon impact with a surface (Figure 12) or the elastic bed used in a circus performance (Figure 13). These videos effectively demonstrate the action of elastic energy and elastic force, as illustrated.

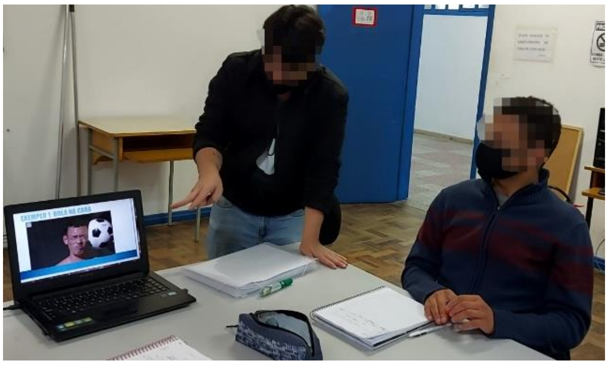


Fig. 12 - Presentation of throwing a soccer ball filled with water at a man's face.

Fig. 13 - Cirque du Soleil Presentation - Ovo video.

VI. Final considerations

The main objective of this research was to investigate the use of an IEU and, based on the results presented in the previous section and inspired by Zabala (1998), we can conclude by answering the following questions:

1) How has our proposal helped to improve (or not) educational practice for the deaf in the school we researched?

2) What experiences, models, examples, and teaching proposals were suitable, or not suitable, for implementation in this research?

3) How could the results obtained by other researchers in other educational contexts (or not) be fully or partially applied to our deaf education context?

4) What empirical results can justify the use of Cognitive Mediation Networks Theory (CMNT) for deaf people, and do they have a validity regime that really confirm our methodology and this Learning theory?

5) Do the results apply only to deaf students, regardless of the starting point, or without considering the conditions in which we find ourselves and the means at our disposal, or can they be expanded to other educational contexts through Universal Design for Learning?

Regarding the first question, we observed on-site that the IEU provided a unique opportunity to address various aspects of the students' education, specifically the different levels of physical phenomena representation related to Mechanical Energy and its conservation. Initially, the surveyed students had a limited understanding of the concept of energy, confining it to electrical energy. However, by the end of the teaching and learning process, there was a significant shift in their attitude, indicating that our proposal was successful.

Considering the second question, we observed that the resources used were mostly suitable for the participating students, with the exception of three closely related to communication, which are:

a) The VidAnalysis-free application which, contrary to the results obtained by Moraes (2019), proved to be unsuccessful due to logistical problems such as lack of internet access and storage space on the cell phones of some students, and especially because it is all in English;

b) The automatic translation plugin was used briefly during a video presentation, but it did not provide an adequate translation, which was criticized by the teacher;

c) The written questionnaires, because they made the students uncomfortable, and it is a concern for future researches: To consider only video recording when dealing with deaf students.

With regard to question 3, we would like to indicate that the activities originally planned had to be modified a few times, for several reasons, including, directly and indirectly, the Covid-19 pandemic itself. Initially, we had planned a pilot test for 2020; however, the global situation from March of that year prevented this pilot test from taking place.

We should also note that, before the pandemic, the activities designed for this research were intended to be conducted in person. However, due to the interruption and subsequent shift to remote teaching, we had to adapt the entire research process, creating, and modifying content for remote instruction. When the application window of the IEU was finally aligned with the teacher's curriculum planning, we returned to face-to-face teaching.

Even so, the modifications made for remote teaching were timely. Among these changes, we created two simulations in the Scratch application, which facilitated the activities execution. These simulations can be run directly in a browser on a cell phone or computer in a plug-and-play style, without needing to install any plugins, apps, or software.

For instance, the Scratch simulation of a bowling ball falling replaced the use of Modellus software (Wolff, 2015), while the simulation of a child in a jumper replaced the “Trapezist Energy” simulation from USP's LabVirt. Both were adapted from Scratch programming platform projects. Their development was necessary and important because, in 2020, the use of the JAVA plugin for browsers was discontinued, making it impossible to use some simulations available on the International Bank of Educational Objects (IBEO).

Regarding the fourth question, we believe that the results presented in the previous section has evidence that supports the effectiveness of CMNT as a suitable theoretical framework for this research. From the perspective of psychophysical mediation, we observed students interacting with experiments throughout the IEU, highlighting the sensory level aspect of representing physical phenomena (Gabel, 1993). From the perspective of social mediation, we notified the importance of face-to-face teaching, which was clear in the dynamic interactions among the participants, allowing us to draw parallels between student engagement during remote and face-to-face classes.

In this sense, there is greater participation, putting social aspect as particularly important in the education, either by ending the linguistic isolation imposed by physical distance during remote classes, or by the faster *feedback* between teacher and student that takes place in person. From Cultural Mediation point of view, we saw the students' interest increase when they had contact with contextualized teaching, and we chose to use Skateboarding as a cultural factor for teaching Physics, taking advantage of this sport projection in its debut at the Tokyo Olympics - 2020, which culminated in the implementation of the IEU. We work on some content with circus art, which demonstrates how physical knowledge is present in many human activities, and how we can enrich the high school physics curriculum by using contexts that are close to the student's reality.

And the hyper cultural mediation that permeates this work is particularly noteworthy. This is evident in the majority of the classes, where slides are accompanied by animated gifs that illustrate physical concepts like the operation of a force. Other examples include the use of simulators, cellphones to assist with Portuguese writing, and internet research to present an image of a location or object that the students were unsure of or concerned about. We believe that the application of CMNT has been beneficial for all of these reasons.

The answer to the fifth question, in conclusion, is that we plan to work on creating additional IEU. Those will cover additional topics related to modern and classical physics, such as elementary particles, quantum mechanics, relativity, ionizing radiation, waves, optics, and electromagnetism. But we would like to do more. We hope that the teaching strategies recommended in this article can be applied in some way to mainstream, special, or inclusive education settings. Our key research opportunities for the future are these two teaching modalities: inclusive and special education. Research in these areas is essential since the needs of these educational environments are more pressing.

This is a challenging task, since it requires developing multifaceted techniques that consider the unique needs of each student – whether they are autistic, sighted, hearing, deaf, deaf-blind, neurotypical, blind, or have limited vision. When considering students with limited vision or blindness, for instance, we find that many of the tactics utilized in the IEU described in this study undergo significant modifications. We shall limit our discussion of these modifications to theoretical and purely conjectural. Clearly, for the deaf student, for instance, the emphasis on the visual component (Campello, 2008) would shift to the tactile and auditory aspects (Camargo, 2012), emphasizing even more on psychophysical cognitive mediation in the case of the blind or low-vision student. And new IT resources should be considered, whether analog or digital, such as the screen reader for simulations.

Some of the experiences listed here may be updated or replaced by others. This is the case with the skateboard track (seen in the simulation and reports), which might be substituted by a toy track with a ramp or loop (e.g., hot wheels) to illustrate energy conservation principles in a tactile way for blind students. The two experiments (toy car and falling balls) can be kept, but the tactile and sound aspects should be emphasized, such as having the student feel the trolley experiment and check the lines and pulleys used to convert the counterweight's gravitational potential energy into kinetic energy in the trolley.

Blind students can also listen to the sound of the ball falling from various heights and relate the energy dissipation to the diverse noises and form of the ball after it strikes the ground. It is also possible to make the ball fall into the student's hand from various heights, allowing him to feel the different intensities of the impact with his hand, demonstrating that the higher the height, the more potential energy the ball has, and the faster it travels until it reaches his hand, when gravitational potential energy is converted into kinetic energy.

It may appear unduly complex, but even phenomena that are invisible to students' senses can be addressed. This is the case while teaching optics to blind students (Camargo, 2012; Silveira; Barthem; Santos, 2019) or sound waves to deaf students (Lang, 1981; Truncale; Graham, 2014; Vongsawad *et al*., 2016). As a result, as previously stated, we emphasize the importance of establishing new IEU, and we hope to disseminate the findings of this study so that other researchers become aware of the issues raised in this case study, with the goal of generating reflection and more involvement, and possibly fostering interest in this cause, Special Education and/or truly inclusive education.

Acknowledgements

Fundação de Amparo à Pesquisa do Estado do Amazonas (FAPEAM) for financial support.

References

AUSUBEL, D. P. **Aquisição e retenção de conhecimentos:** uma perspectiva cognitiva. Lisboa: Plátano, v. 1, 2003.

BERNARDINO, E. L. A. O uso de classificadores na língua de sinais brasileira. **ReVEL**, v. 10, n. 19, 2012.

BRASIL. Ministério da Educação. Secretaria da Educação Básica. **Base nacional comum curricular**: Ensino Médio. Brasília, DF, 2020. Disponível em: http://basenacionalcomum.mec.gov.br/images/historico/BNCC_EnsinoMedio_embaixa_site_110518.pdf. Acesso em: 16 de abril de 2020.

CAMARGO, E. P. **Saberes docentes para a inclusão do aluno com deficiência visual em aulas de Física**. São Paulo: Editora Unesp, 2012.

CAMPELLO, A. R. S. **Aspectos da visualidade na Educação de Surdos**. 2008. 245 f. Tese (Doutorado) - Curso de Doutorado de Educação, Universidade Federal de Santa Catarina, Florianópolis.

CAROBIN, C.; ANDRADE NETO, A. S. Um exemplo do uso de simulações computacionais aplicados no ensino de equilíbrio químico para estudantes de ensino médio. **Encontro Nacional de Pesquisa em Educação em Ciências**, v. 4, p. 144-145.1, 2003.

ESQUEMBRE, F. Computers in physics education. **Computer physics communications**, v. 147, n. 1-2, p. 13-18, 2002.

FREITAS, S. A. **Um estudo da utilização didática de ferramentas de cognição extracerebrais por estudantes do ensino fundamental:** evidências de aprendizagem Significativa do modelo do átomo de Bohr. (Dissertação de Mestrado). Curso de Mestrado em Ensino de Ciências e Matemática, Universidade Luterana do Brasil, Canoas, 2019.

FREITAS, S. A.; ANDRADE NETO, A. S. Use of different external mediating mechanisms of the Bohr atom model: Evidence of Meaningful Learning through verbal-gestural analysis in elementary school students. **Acta Scientiae**, v. 21, n. 4, p. 133-148, 2019.

GABEL, D. L. Use of the particulate nature of matter in developing conceptual understanding. **Journal of Chemical Education**, v. 70 n. 3, p. 193-194, 1993.

HALLIDAY, D.; RESNICK, R.; WALKER, J. **Fundamentos de física. v. I: mecânica**. Tradução: Ronaldo Sérgio de Biasi. 10. ed. Rio de Janeiro: LTC, 2016.

HEWITT, P. G. **Física conceitual** [recurso eletrônico] Tradução: Trieste Freire Ricci. Revisão técnica: Maria Helena Gravina. 12. ed. Porto Alegre: Bookman, 2015.

KASSAR, M. C. M. Educação especial na perspectiva da educação inclusiva: desafios da implantação de uma política nacional. **Educar em revista**, n. 41, p. 61-79, 2011.

LANG, H. G. Acoustics for deaf physics students. **The Physics Teacher**, v. 19, p. 248-249, 1981.

MINAYO, M. C. (Org.). **Pesquisa Social:** teoria, método e criatividade. Petrópolis: Vozes, 2013. 111 p. (Coleção Temas Sociais).

MORAES, E. P. **Implementação de Unidade de Ensino Potencialmente Significativa no ensino da Cinemática e introdução ao conceito de energia**. 2019. 159 f. Dissertação (Mestrado) - Curso de Mestrado Profissional em Ensino de Física, Universidade Federal Fluminense, Volta Redonda. Cap. 8

MORALES, T. G. T.; DE CARVALHO, H. A. P.; PHILIPPSEN, G. S. Sequência didática sobre ondas sonoras: relato de uma experiência docente na educação de jovens e adultos inclusiva para surdos. **Brazilian Journal of Development**, v. 6, n. 11, p. 84689-84699, 2020.

MOREIRA, M. A. **Unidades de ensino potencialmente significativas UEPS.** Porto Alegre: UFRGS, Instituto de Física, 2011.

MORTIMER, E. F. **Linguagem e formação de conceitos no ensino de ciências**. UFMG, 2000.

NEVES, C. E. B. Desafios da educação superior. **Sociologias**, n. 17, p. 14-21, 2007.

OATES, E. **Linguagem das mãos**. Aparecida, SP: Santuário, 1969.

PERLIN, G. T. **Histórias de vida surda:** identidades em questão. 1998. 51 f. Dissertação (Mestrado em Educação) - Curso de Mestrado em Educação, Universidade Federal do Rio Grande do Sul, Porto Alegre. Cap. 4.

PERLIN, G. T. As diferentes identidades surdas. **Revista da FENEIS,** ano IV, n. 14, p. 15-16, 2002.

PERLIN, G. T. Cultura e educação bilíngue no pulsar das identidades surdas contemporâneas. **Educação de surdos em debate**. Curitiba: UTFPR, p. 223-232, 2014.

PERRY, G. T.; ANDRADE NETO, A. S. Estratégia de design do software equil, uma simulação para ensino de equilíbrio químico e sua comparação, em sala de aula, com o software le chat 2.0. In: V ENCONTRO NACIONAL DE PESQUISA EM EDUCAÇÃO EM CIÊNCIAS, 2005.

PICANÇO, L. T. **O ensino de óptica geométrica por meio dos problemas de visão e as lentes corretoras**: uma unidade de ensino no contexto da educação inclusiva para surdos. 2015. 190 f. Dissertação (Mestrado) – Curso de Mestrado Profissional em Ensino de Física, Universidade Federal do Amazonas, Manaus. Cap. 5.

PICANÇO, L. T; CABRAL NETO, J. S. Uma Unidade de Ensino de Óptica Geométrica para surdos e ouvintes. **Experiências em Ensino de Ciências**, Cuiabá, v. 12, n. 8, p. 31-48, 2017.

PICANÇO, L. T.; ANDRADE NETO, A. S.; GELLER, M. O Ensino de Física para Surdos: o estado da arte da pesquisa em educação. **Revista Brasileira de Educação Especial**, Bauru, v. 27, p. 391-410, jan. 2021. DOI: http://dx.doi.org/10.1590/1980-54702021v27e0123.

PICANÇO, L. T. **Construindo significados sobre o conceito de energia:** Resultados de uma Unidade de Ensino Inclusiva aplicada a estudantes surdos do ensino médio em tempos de pandemia. 2022a. Tese (Doutorado em Ciências e Matemática) - Universidade Luterana do Brasil, Canoas.

PICANÇO, L. T.; ANDRADE NETO, A. S.; GELLER, M. A mediação cognitiva por meio de recursos digitais de Tecnologia Assistiva para estudantes surdos: realidade, expectativas e possibilidades. **Revista Brasileira de Informática na Educação**, [S.L.], v. 30, p. 50-72, mai. 2022b. DOI: http://dx.doi.org/10.5753/rbie.2022.2395

PICANÇO, L. T.; ANDRADE NETO, A. S. de; GELLER, M. Desafios, adversidades e lições para o ensino de Física para alunos surdos em tempos de pandemia de Covid-19. **Revista Educação Especial**, [S. l.], v. 36, n. 1, p. e24/1-26, 2023. DOI: 10.5902/1984686X66206.

QUADROS, R. M. de (Org.). **Estudos surdos I**. Petrópolis, RJ: Arara Azul, 2006.

ROALD, I.; MIKALSEN, O. What are the Earth and the heavenly bodies like? A study of objectual conceptions among Norwegian deaf and hearing pupils. **International Journal of Science Education**, v. 22, n. 4, p. 337-355, 2000.

ROSENTHAL, G. **Interpretive social research**: An introduction. Universitätsverlag Göttingen, 2018.

SCHWARTZMAN, S.; BROCK, C. **Os desafios da educação no Brasil.** Rio de Janeiro: Nova Fronteira, 2005.

SILVEIRA, M. V.; BARTHEM, R. B.; SANTOS, A. C. Experimental didactic proposal for inclusive teaching of waves in high school. **Revista Brasileira de Ensino de Física**, v. 41, n. 1, 2019.

SOUZA, B. C. **Teoria da mediação cognitiva**: os impactos cognitivos da hipercultura e da mediação digital. 2004. 282 f. Tese (Doutorado) - Curso de Psicologia, Universidade Federal de Pernambuco, Recife. Cap. 6.

SOUZA, B. C. *et al.* Putting the Cognitive Mediation Networks Theory to the test: Evaluation of a framework for understanding the digital age. **Computers in Human Behavior**, v. 28, n. 6, p. 2320-2330, 2012.

SWELLER, J. **Cognitive Load Theory**: a special issue of educational psychologist. LEA. 2003.

THOMA, A. S. **Cultura e avaliação**: a diferença surda na escola. Santa Cruz do Sul: EDUNISC, 2009.

TREVISAN, R.; ANDRADE NETO, A. S. A Utilização de Ferramentas Hiperculturais no Ensino de Mecânica Quântica: Investigação do Aprendizado de Representações, Drivers e Conceitos Quânticos. **RENOTE Revista Novas Tecnologias na Educação**, v. 12, n. 2, 2014.

TREVISAN, R.; ANDRADE NETO, A. S. Bancadas virtuais e storyboards com ilustrações microscópicas representativas como recursos no estudo da Mecânica Quântica. **Revista Brasileira de Ensino de Ciências e Matemática**, v. 2, n. 2, 2019.

TRUNCALE, N. P.; GRAHAM, M. T. Visualizing Sound with an Electro-Optical Eardrum. **The Physics Teacher**, v. 52, n. 2, p. 76-79, 2014.

VARGAS, J. S.; GOBARA, S. T. Sinais de libras elaborados para os conceitos de massa, força e aceleração. **Revista Polyphonía**, v. 26, n. 2, p. 187-202, 2015.

VONGSAWAD, C. T. *et al.* Acoustics for the Deaf: Can You See Me Now? **The Physics Teacher**, v. 54, n. 6, p. 369-371, 2016.

VYGOTSKY, L. S. **Teoria e método em psicologia**. São Paulo. Martins Fontes, 2004.

WOLFF, J. F. S. **Qual a mudança na estrutura cognitiva de estudantes após o uso de simulações computacionais? Uma investigação da relação entre representações computacionais internalizadas e aprendizagem significativa de conceitos no campo das colisões mecânicas em física.** 2015. 332 f. Tese (Doutorado em Ensino de Ciências e Matemática) - Universidade Luterana do Brasil, Canoas. Cap. 8.

YAMAMOTO, K.; FUKE, L. F. **Física para o ensino médio, v. 1: mecânica**. 4.ed. São Paulo: Saraiva, 2016.

ZABALA, A. **A prática Educativa**: como ensinar. Tradução: Ernani F. F. Rosa. Porto Alegre: Artmed, 1998.