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An inclusive approach to incorporating green chemistry in a post-pandemic world

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Abstract

The Covid-19 pandemic brought several challenges to the educational system with regard to the continuity of classes in the context of an Emergency Remote Education (ERE). Among these challenges, we highlight the intensification of disinterest and low participation of students in chemistry classes and the insufficiency of didactic proposals that work with School Inclusion (SI), with a focus on accessibility for the deaf. The ERE model lasted 2 (two) years, after this period, teachers had to face a new change in the school scenario: Post-pandemic Face-to-Face Teaching (post-pandemic FFT). Thus, with the return to classes, the challenges mentioned were accentuated, bringing again the demand for the adoption of new educational strategies. Within this context, this article is justified in the development of a pedagogical intervention focused on the inclusive teaching of Chemistry in the post-pandemic FFE, linked to the principles of Green Chemistry (GC) and the 6th Sustainable Development Goal (SDG). This action aimed at the elaboration of accessible didactic materials, together with the application of an experimental, contextualized, and sustainable practical class called: Batch Adsorption with activated charcoal from the endocarp of the coconut (biodegradable adsorbent). The results of the research showed that the adoption of the contextualization methodology, concomitantly with the development of the practical activity, pointed to an improvement in the teaching of Chemistry in the post-pandemic face-to-face model. Therefore, sustainable experimentation effectively contributed to the learning process and a more critical look at the socio-environmental issues discussed.

Keywords: accessibility; deafness; inclusive green chemistry; systems thinking; LIBRAS.

1. Introduction

The advance of the COVID-19 pandemic brought to the educational scenario several challenges for the continuity of classes in the context of an Emergency Remote Education (ERE). With this new reality in which educators and students were inserted, the search and use of diversified pedagogical strategies and methodologies was fundamental for the elaboration of classes in the ERE (Souza, Figueirêdo, Silva Júnior, Ferraz & Tavares, 2022; Aljedaani, Krasniqi, Aljedaani, Mkaouer, Ludi & Al-Raddah, 2022; Romão & Silva

Júnior, 2022). However, there were several impasses that plagued the school reality in the remote period, among which there is the intensification of disinterest and low participation of students in classes, especially with regard to the teaching of Chemistry (Lima, Silva & Pinheiro, 2021; Silva Júnior, Iran Filho, Romão & Dias, 2022).

The ERE model had an average duration of 2 (two) years, in most Brazilian institutions, after this period there was a new change in the school scenario, the return of face-to-face classes, called Post-pandemic Face-to-face Teaching (post-pandemic FFT). However, with the return to classes, the challenges mentioned were prominent, once again bringing the demand for the adoption of educational strategies. In this sense, the lack of interest of high school students in the discipline of Chemistry in all its dimensions, especially the socio-environmental, showed the need to promote pedagogical interventions also in the post-pandemic FFT.

According to Silva Júnior (2017), the insufficiency of didactic proposals that relate Chemistry and its socio-environmental issues is even more aggravating when referring to the work of School Inclusion (SI), with a focus on accessibility for the deaf. This setback is, according to the author, the result of the lack of accessible methodologies for such audiences that address, for example, the principles of Green Chemistry (GC) linked to the Sustainable Development Goals (SDGs).

According to Anastas and Warner (2000), GC is an area of Chemistry that aims to reduce the production of harmful and toxic by-products, focusing on the development of procedures that are harmless to human and environmental health. The SDGs, on the other hand, are 17 (seventeen) global objectives "fundamental for social fullness, since such actions have the purpose of effectively implementing constitutional rights" (Figueirêdo, Silva Júnior, Ferraz & Souza, 2022, p. 11248), since they are based on several environmental, social, and economic challenges, for a total or partial resolution by the year 2030. Recently, creative resources provided the interaction between the principles of GC and Sustainable Development (Da Silva Júnior, De Jesus & Girotto Júnior, 2022).

Concerning the process of inclusion of deaf people, this still presents itself as a challenge for the various educational institutions, much of this is due to the history of repression and capacitance in which the Deaf Community (DC) developed. Among the various episodes of discrimination and segregation, it is possible to mention the oralist movement, in which Sign Language was prohibited in order to "normalize" the deaf (Perlin & Strobel, 2006; Vieira & Molina, 2018; Tavares et al., 2022a, 2022b;). With this, the experience of deaf people went through numerous turbulences until the rise of bilingualism, which is essential for effective DC learning (Tavares, 2022; Da Silva Júnior et al., 2022).

In Brazil, the Law of Guidelines and Bases of National Education (LDB) No. 9.394/1996, emphasizes the need for adequacy of schools in the care of SI, from the adaptation of the methodologies used in classes, to the development of teaching materials (Brasil, 1996). In contrast, this is a considerably difficult process due to the misinterpretation of the term "inclusion", since schools end up "integrating" students and not including them effectively, forcing students to "adapt" to the profile of the educational institution, not respecting its individuality (Trevisan, 2018).

Thus, it is understood the need for improvements in the approaches to SI present in both the ERE and post-pandemic Face-to-face Teaching. Strobel (2008) highlights as an alternative to this, the presence of "Cultural

Artifacts" of DC, namely: the acquisition of knowledge and communication with the world through the Visual Experience; the use of Sign Language, which is the door to access information; and deaf literature that allows the insertion of listeners in the community.

In addition, Tavares et al. (2022a) indicate that the deaf learning process requires mediation between these students and the programmatic subjects of the Chemistry discipline, so that such action is due to the contextualization methodology with the student experience. In this context, the association between the aforementioned discipline and the water theme emerges as a tactical parameter, given that this theme for Prado et al. (2018, p. 8) "imposes on the global community challenges of bringing water, in adequate quantity and quality, for all", this being SDG 6 (Drinking water and sanitation). Quadros (2004) confirms this premise, indicating that this is a very present content in the lives of students.

In this sense, the activity of contextualizing the water theme with the environmental aspect of Chemistry still opens space for the adoption of an experimental methodology, since it genuinely helps students' cognition in chemical phenomena and concepts. Salesse (2015, p. 45) corroborates this perspective, indicating that experimental procedures have the function of "making theory come true", functioning as a learning enhancing tool.

Within this context, the article in question is justified in the development of a pedagogical intervention focused on the inclusive teaching of Chemistry in post-pandemic FFT, linked to the principles of GC and SDG 6. This action aimed at the development of didactic materials accessible to deaf and hearing people, along with the application of an experimental, contextualized and sustainable practical class. This action sought to assist the process of school education and citizenship of all members of the research.

2. Methodology

The research in question was based on a qualitative methodological approach with a participant nature, since this type of research is of great value, as it reflects the understanding of the researchers and researched, gradually inserting their experiences in the context of the object of study (Cruz, 2020).

In this follow-up, the action was developed by the research group Inclusion in Chemistry Teaching at the Federal Institute of Paraiba (IFPB), composed of three professors in the Chemistry area, one of them being also an SLT, two undergraduates and one graduate of the Chemistry Degree Course of the IFPB. It is worth mentioning that this research project was evaluated and approved by the Research Ethics Committee (CEP) of IFPB, according to the number of Certificate of Presentation of Ethical Assessment (CAEE): 57464422.1.0000.5185, as regulated by Brazilian legislation (Brasil, 2012).

The progress of the application of the research project took place in 2022, with the return of IFPB's face-to-face classes, João Pessoa *campus*. The main objective of this intervention was to analyze the expansion of methodologies aimed at an SI in post-pandemic FFT, focusing on the discipline of Chemistry involved in the perspectives of EE.

The project was applied in a class of the 4th year of the Technical Course in Environmental Control Integrated to High School of IFPB, João Pessoa *campus*, composed of 21 (twenty-one) hearing students and 1 (one) deaf student. In addition, during the development of the work, 3 (three) IFPB SLT were present at all times. The

methodological procedure of the research project was divided into 3 (three) stages, according to Table 1.

Table 1. Research Methodology Moments.

Moments	Description
Step 1: Meetings with SLT and the development of teaching materials.	A moment prepared for an exchange of ideas between the SLT and the researchers, in order to gather information for the construction of didactic materials accessible to the class, from the perspective of the post-pandemic FFT. With this, the class resources were elaborated and produced. They went through a review of the SLT. At this stage, it was possible to analyze the main differences between the production of inclusive materials for the ERE and the post-pandemic FFT.
Step 2: Application of a Bilingual Virtual Survey Instrument (BVSI).	The BVSI, developed in *Google Forms*, was a bilingual digital evaluative instrument (in Portuguese and in the Brazilian Sign Language - LIBRAS), composed of 3 (three) questions*: 1). Do you know the Sustainable Development Goal 6?; 2). Do you know Green and Sustainable Chemistry?; 3). Have you ever studied with inclusive teaching materials on Green and Sustainable Chemistry and the Sustainable Development Goal 6? If yes, exemplify.* The aforementioned investigative instrument sought to verify the level of understanding of the students regarding the content treated.
Step 3: Application of classes on GC, SDG 6 and the development of a sustainable experimental practical class.	Based on the information from the BVSI, a contextualized theoretical class on GC and SDG 6 was developed and applied. In order to instigate the participation of students, a sustainable experimental practice was also applied in the Chemistry laboratory for the inclusive class. To validate the action, an observational analysis was performed in the class during all moments of the application.

3. Results and Discussion

3.1 Step 1: Meetings with SLT and the development of teaching materials

In agreement with the methodological path of the research, the first moment of the project was through meetings between researchers and the SLT. These meetings aimed to situate the group regarding the changes resulting from the return to IFPB face-to-face classes. In these meetings, questions were raised about the assembly and/or adaptation of the teaching resources that were used in the classes.

In the FFT model of the IFPB, the SLT accompany the deaf students throughout the class, differently from what occurred in the ERE, in which the simultaneous translation of LIBRAS by the SLT in synchronous meetings did not always occur adequately, becoming a great challenge. However, this problem was solved

with the return of face-to-face classes, however, other deadlocks were observed, such as the need to produce and use accessible teaching materials aimed at the deaf.

Even with the skills acquired by teachers during the pandemic period, the process of reviewing the SLT in the class materials was essential, since these pedagogical resources still had accessibility flaws, such as the excess of texts and the use of images with low quality that made it difficult to view the resources. Figures 1 and 2 show one of the aforementioned alterations. This data corroborates the idea that SI is due to the collaborative work of the entire pedagogical team, causing teachers to develop the ability to acquire new skills in partnership with school support networks, fulfilling their role as mediator and facilitator of teaching (Karagiannis, Stainback & Stainback, 1999; Mwirichia, Kathuri & Mariene, 2017; Clark et al., 2021).

Figure 1. Before reviewing the SLT, visualization made difficult due to the size of the images.

Figure 2. Post revision of the SLT, in which the suggestion was to focus on the SDG worked, increasing the source.

In addition to the interactive slide materials for the classes, there was also the construction of Complementary Bilingual Instruments (CBI), this creation aimed to rescue one of the DC Cultural Artifacts, which is the appreciation of the Sign Language. Souza and Silveira (2011) argued that the use of LIBRAS signs in Chemistry classes foster actions that enable "the relationship of the deaf with chemical knowledge and also with their colleagues, teachers and school community" (Souza & Silveira, 2011, p. 42). With this in the construction of the CBI, there was great emphasis on the guiding terms of the LIBRAS research project, such as Green Chemistry and Sustainability. Figures 3 and 4 demonstrate the LIBRAS translation of these concepts present in the CBI.

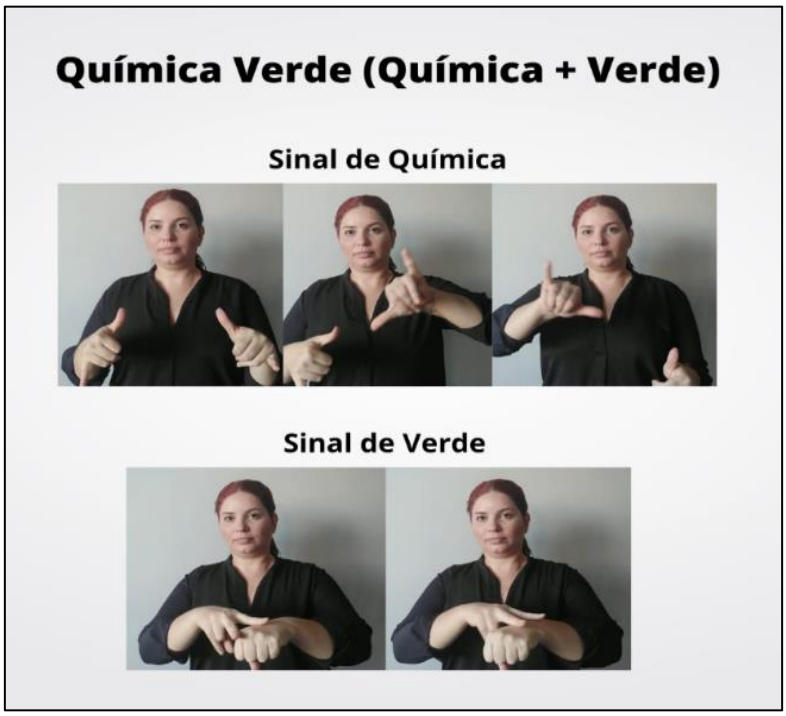

Figure 3. LIBRAS translation of the term "Green Chemistry".

Figure 4. LIBRAS translation of the term "Sustainability".

One of the CBIs was the BVSI developed in *Google Forms.* The assembly of this digital resource followed the steps listed: creation of questions contextualized to the theme of the project; audio recording of these issues; sharing of audios with the SLT to facilitate the process of translation in LIBRAS; filming of translation in LIBRAS and posting of videos on *YouTube*; development of the form with the SLT video. It is noteworthy that the other CBIs followed a procedure similar to this one.

3.2 Step 2: Application of a Bilingual Virtual Survey Instrument (BVSI).

With the application of the BVSI in the class, it was observed a great distance from the students regarding the guiding environmental themes of the research project, since most of the students, with the exception of those who had already participated in previous interventions developed by the researchers (in the ERE), claimed to be unaware of SDG 6 and GC. This cognitive distancing expresses the need for a new explanation on the themes. This result can be considered as an educational obstacle related to a traditional and decontextualized teaching, which is very recurrent in elementary schools, even though Environmental Education (EE) has numerous interdisciplinary issues to be worked on, especially in the field of Chemistry, is not yet satisfactorily addressed by teachers in this area (Farias, 2021; Silva Neto & Araújo, 2021).

According to the first result of the BVSI, these same students indicated that they did not have experiences with classes related to the aforementioned contents that were also developed through inclusive materials. This information shows how basic education distances itself from the principles of meaningful learning. According to Lanuti (2015), education can only be considered significant when everyone has space to build their own knowledge. Thus, without SI, this development of students' potential and autonomy is impossible, conditioning demotivation and disinterest in the classroom.

These data are worrying in two ways, the first is that the students of the studied class are graduates of a Technical Course in Environmental Control and, even so, they informed that they have never had contact with themes so relevant and present in this area and in the High School Nacional Exam (ENEM), in Brazil (Da Silva Júnior & Lopes, 2021; Tavares et al., 2022c). And second, it is an inclusive class, so it is an alarming fact that these students do not have experiences with explaining themes in their area of study, in a way accessible to all. The need for educational actions and interventions that promote an inclusive and meaningful education for all students, such as the present research, is once again evidenced with the analysis of the survey instrument.

3.3 Step 3: Application of classes on GC, SDG 6 and the development of a sustainable experimental practical class.

According to the results of the BVSI, the contents of GC and SDG 6 were discussed in the classroom and the contextualization methodology was intensified at this stage of application. In addition, with the return of face-to-face classes and access to the Chemistry laboratory, the research group decided to expand the contents mentioned along with a sustainable experimental practice, since experimentation as an interlocutor to contextualization, through experiments that are easy to manipulate and execute, "ends up dispersing scientific knowledge with the student's context" (Coelho & Lima, 2020, p. 130).

One of the main previous checks acquired at this time of application was the low interaction between the hearing students and the deaf student. This analysis was performed through an observational environment in the classroom, in which it was found that before classes the deaf student communicated only with the SLT, while the other students talked away. In this sense, this first face-to-face contact with the class reinforced the idea of "integration", recurrent in schools that call themselves inclusive, in which the lack of inclusion and accessibility makes communication between deaf and listeners difficult (Da Silva Júnior & Figueirêdo 2017; Tavares et al., 2022b)

In this circumstance, there was a theoretical explanation of the contents that was based on topics that related Chemistry with its socio-environmental issues, in which there were debates about drinking water, basic sanitation, management, distribution, treatment and water quality, involved in the principles of GC and SDG 6. The most discussed topics among the students were the social perspectives involved in the process, in these debates the whole class began to interact more effectively, through the sharing of experiences and doubts related to the subject.

Subsequently, a theoretical content that supported the experimental class was presented to the class, in partnership with SLT, which was the adsorption process for water treatment. Adsorption is a physicochemical phenomenon that occurs when a liquid or gaseous phase adsorbate (adsorbate) adheres to the surface of a solid phase adsorbent (material that adsorbs the adsorbate). This is a procedure used in several applications (Gasper & Pitol-Filho, 2016), which when focused on a water treatment technique is presented as a low-cost and easy-to-perform method, especially when it comes to a batch experiment, being a viable alternative for high school. Depending on the nature of the adsorbent, it may still present itself as a sustainable procedure. Based on this notion, the experimental class used the described method and was entitled: *Batch Adsorption with activated*

charcoal from the endocarp of the coconut (biodegradable adsorbent). GC and SDGs aim at scientific and technological advances that ensure the overcoming of socio-environmental problems, with the purpose of enabling means for people to achieve quality of life. Thus, both themes mentioned relate and complement each other directly with the activity promoted by the research group.

Thus, the experiment related the importance of sustainable and low-cost treatment processes for the analysis and improvement of water quality, reducing impacts such as pollution, dumping and minimizing the release of chemicals dangerous to the health of the ecosystem. As a way to mitigate the problems of water demand, adsorption through activated carbon from the endocarp of coconut, presents itself as an economically viable and efficient method, acting as a sustainable alternative in the supply of a greater good to the population.

In the laboratory, there was an effective participation of students in the execution of the stages of the experimental script, since the teachers and the SLT only mediated the activity, so that all actions, such as the handling of the glassware, weighing, measuring the volume of the reagents, collection and analysis of the results, were developed by the inclusive class. Figure 5 shows some records of this third moment of application of the research project.

Figure 5. Inclusive class performing the experimental practice procedures.

The qualitative verification carried out during the described procedure enabled the observation of interest and interactivity among students in carrying out the demands of the experimental script. This follow-up was fundamental for the validation of the teacher intervention, since before the activities proposed by the group, the interactive process was almost nonexistent among the students (listeners and deaf).

This condition can be understood as a result of the application of an experimental and contextualized methodology in the class, which, in addition to having a sustainable profile, was also supported by the principles of SI, both for enabling the active participation of deaf students in the development of the experiment, and for intensifying the sense of their visuality. Figueirêdo et al. (2018) argue that methodologies, such as experimentation, that explore the visual aspects of students, are characterized as an excellent resource for the education of the deaf. In this sense, the school space researched took a genuinely inclusive and

instigating profile for the students participating in the research project.

4. Conclusion

This action demonstrated that the promotion of interactive classes, based on the concepts of inclusion and exchange of knowledge, generates the awakening of interest in knowledge. Thus, it was noted that the adoption of the contextualization methodology, concomitantly with the development of the practical activity, pointed to an improvement in the teaching of Chemistry in the post-pandemic face-to-face model, as could be observed after the application of the pedagogical intervention in question.

The environmental and sustainable theme in the teaching of Chemistry effectively contributed to the learning process, making students understand in a meaningful and critical way the contents discussed in the classroom. Nevertheless, Environmental Education should remain increasingly present in classrooms, with the active participation of teachers and students in all types of teaching, including the particularities of all students.

Regarding the work with deaf students, it is essential that the pedagogical team works together in the creation and/or adaptation of more accessible materials and methods, focusing on the use of visual resources, being essential, the performance of SLT in the inclusive classroom, as well as the intensification of LIBRAS in the production of class materials.

In addition, this research intends to add to the educational sector skills and abilities related to the work of SI, since the discussions raised throughout this article, evidenced the importance of teacher innovation in all circumstances and potential challenges in the educational field.

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