PRÁTICAS EDUCATIVAS, MEMÓRIAS E ORALIDADES

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Proposal for an educational product on chemical equilibrium for blind students

EDUCATIONAL PRODUCT

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Abstract
With the increasing number of blind students enrolled in regular Basic Education classes, there is a need to think about mechanisms that favor the effective inclusion of these students. This article presents a proposal for an Educational Product designed for blind students. The teaching material discusses the concept of Chemical Equilibrium (CE), more specifically, the effect of concentration on the displacement of CE. The objective is to offer an inclusive, accessible and autonomous learning experience, overcoming barriers in understanding complex Chemistry concepts. The proposal includes tactile material for use in the classroom and outside, as well as auditory approaches with audio classes and exercises available on the "Estudaki" application. These strategies seek to contribute to the effective inclusion of these students in the educational environment. This study highlights the importance of inclusive approaches in science education and offers contributions to the development of more accessible pedagogical practices in the area of Chemistry.
Keywords: Educational Product. Chemical Equilibrium. Visual Impairment.

Proposta de produto educacional sobre equilíbrio químico para estudantes cegos

Resumo
Com o número crescente de estudantes cegos matriculados em turmas regulares da Educação Básica, surge a necessidade de pensarmos em mecanismos que favoreçam a inclusão efetiva desse alunado. Este texto traz uma proposta de Produto Educacional elaborado para estudantes cegos. O material didático discute o conceito de Equilíbrio Químico (EQ), mais especificamente, o efeito da concentração no deslocamento do EQ. O objetivo é oferecer uma experiência de aprendizado inclusiva, acessível e autônoma, superando as barreiras na compreensão de conceitos complexos de Química. A proposta inclui material tátil para uso em sala de aula e fora dela, além de abordagens auditivas com áudioaulas e exercícios disponíveis no aplicativo "Estudaki". Essas estratégias buscam contribuir para a inclusão efetiva desses estudantes no ambiente educacional. Este estudo destaca a importância de abordagens inclusivas na educação científica e oferece contribuições para o desenvolvimento de práticas pedagógicas mais acessíveis na área de Química.
Palavras-chave: Produto Educacional. Equilíbrio Químico. Deficiência Visual.

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1 Introduction

According to the Brazilian Education Guidelines and Bases Law (LDB) (Brasil, 1996), learning is a right that must be guaranteed to everyone, following the principles of equality and rights of opportunity.

The Law on the Inclusion of People with Disabilities, Law No. 13.146 of 2015, in its second article, considers people with disabilities (PwD) to be those who have long-term restrictions of a motor, cognitive, intellectual or sensory nature, which, in contact with one or more barriers, may affect their full and effective participation in society (Brasil, 2015).

In addition, established by Decree No. 10,502 of September 30, 2020 (Brazil, 2020a), we have the National Policy for Special Education: Equitable, Inclusive and with Lifelong Learning (PNEE) (Brazil, 2020b), which is aimed at Target Students of Special Education (PAEE)[1]. The document brings to light what Mantoan (2003) advocated, i.e. guidance on actions and strategies for implementing the paradigm of school inclusion, based on modernizing and restructuring the real conditions of most Brazilian schools.

There are a number of difficulties encountered by schools in making the process of school inclusion viable for PAEE students. These difficulties go beyond legal guarantees and architectural adaptation, as compulsory enrollment does not guarantee access to the educational resources that are essential for an effective teaching and learning process, with the participation of these students in all school activities (Borges, 2016).

Considering the obstacles to access to learning for PAEE students, Santos (2007) points out that, in the case of visual impairment (VI), this brings a significant obstacle to the teaching method, requiring educational practices to be planned in such a way as to take into account their specificities.

It is through verbal and/or tactile messages that people with VI interact and understand the physical world, build their elementary perceptions and form mental images

[1] PAEE are students with intellectual, visual, auditory, auditory-visual, physical-motor, deaf-blind, physical and multiple disabilities, global development disorders or high abilities (Brazil, 2020b).

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of people, objects and environments (Bruno, 2006). Bringing it into the educational field, Fernandes, Franco-Patrocínio and Freitas-Reis (2018) argue that "one of the ways the blind learn and understand the world is through touch, we must be attentive to creating teaching strategies that have touch as the main instrument of communication and construction of knowledge" (p. 191).

The use of touch allows for the discovery and expansion of knowledge, and the materials produced should be based on visual parameters that correspond to the characteristics of touch, as well as offering aesthetic attributes, which benefits the imagination (Sá; Simão, 2010). From this perspective, the production of adapted teaching aids helps PAEE students to learn and is a means of facilitating, encouraging or enabling the teaching and learning process. The construction of this type of teaching material, in addition to being seen by sighted or low-vision students, can be touched and manipulated, which enables and favors the learning of all students in the classroom (Carvalho; Gonçalves, 2019).

Data presented by the Anísio Teixeira National Institute for Educational Studies and Research (INEP, 2024) shows that, in 2023, there were 7,321 blind students and another 86,867 with low vision enrolled in our schools. In view of this, this work seeks to contribute to this group of students, who need to have their rights to access learning guaranteed.

Faced with this Brazilian educational panorama, and knowing that there is a latent need to look for differentiated strategies to assist blind students, we initially set about searching for papers that addressed our topic of interest, that is, Chemical Equilibrium (CE). A survey was carried out on academic work search platforms, using the keywords: chemical equilibrium, didactic material, visual impairment, adapted didactic material.

The first platform used was the Portal da Capes. Searches there returned papers that addressed didactic strategies for teaching CE, but none focused on VI. On the Scielo platform, there was also no result of studies focused on this interest.

More specifically in the area of chemistry teaching, a search was carried out in the annals of the National Chemistry Teaching Meeting (ENEQ), between 2004 and 2023, and

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we found no publications that addressed the central theme of this work. The search extended to the journal of the Benjamin Constant Institute (IBC), a national reference in VI and teaching and learning for this audience. Among the articles on chemistry published in the IBC magazine, only one dealt with the creation of an analog model for the study of stoichiometry, by Ferry, Schmidt and Assis (2022).

In general, the searches returned papers on textbook analysis, the use of computer simulations, experimental activities, didactic games and tactile materials, but none focused on the study of CE. These platforms did not present any work on teaching materials adapted for blind or visually impaired students on the subject of CE.

Given this panorama, we believe that this study can contribute to blind students' learning about the concept of CE. We emphasize the importance of adapting resources and strategies to promote inclusive education, with a view to meeting the needs of PNEE students, providing them with the conditions for inclusion in mainstream education. The consolidation of everyone's right to education implies, first and foremost, measures that make it possible to turn the school into an inclusive space with quality education for all, without distinction (Borges, 2016).

In view of the above, this article seeks to disseminate the Educational Product developed in the Course Conclusion Work of the first author of this article and supervised by the second author, in which we focused on the development of adapted activities for the study of CE with a focus on blind students.

2 Theoretical background

2.1 Visual impairment and education

According to the Ministry of Health, through Ordinance No. 3.128/2008 (Brasil, 2008a), a person with blindness or low vision is considered to have low vision. Conde (2004) discusses two ophthalmological scales (visual field and visual acuity) that delimit whether a person has blindness or low vision. It is important to first highlight the complexity

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of delimiting the term blindness. According to Conde (2004, p. 1), "the term blindness is not absolute, as it includes individuals with varying degrees of residual vision. It does not necessarily mean total inability to see, but rather impairment of this aptitude to levels that incapacitate the exercise of routine tasks".

A person is considered blind if:

> the corrected vision of the best of her eyes is 20/200 or less, that is, if she can see at 20 feet (6 meters) what a person with normal vision can see at 200 feet (60 meters), or if the widest diameter of her visual field implies an arc no greater than 20°, even though her visual acuity in this narrow field may be greater than 20/200 (Conde, 2004, p. 1).

Additionally, the person is considered blind because they perceive the world "through the haptic, kinesthetic and auditory systems" (Silva, 2019, p. 84).

A person with low vision is defined as having "visual acuity of 6/60 and 18/60 (metric scale) and/or a visual field between 20° and 50°" (Conde, 2004, p. 2).

Through sight, we can perceive most of the things around us in a fraction of a second. Nowadays, around 80% (eighty percent) of our information is obtained by sight. Over time, radio stations and sound advertising have been replaced by smartphone screens, television sets, billboards and shop windows (Marques, 2018).

Turning our attention to the school environment, the teaching and learning process becomes meaningful when teachers enable students to actively participate in activities. The use of tactile objects is essential so that DV students can develop their own understanding of what is being covered (Dallabona, 2011). "The availability of very simple, handmade resources and adaptations, sometimes built by their own teachers, makes the difference for certain VI students" (Galvão Filho; Damasceno, 2008, p. 19).

For Dallabona (2011), tactile exploration of the material being analyzed aims to identify the characteristics and highlight the greatest number of details, providing recognition of textures, the presence or absence of various components and the consistency of the utensils used.

The use of tactile material in the teaching and learning process is a way of enabling accessibility for VI students, allowing them to learn on equal terms with their sighted

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colleagues. In addition, tactile material enables VI students to feel, explore shapes, textures, reliefs and other characteristics of the objects in question, allowing for a more comprehensive and concrete understanding of the content studied (Silva *et al*., 2023).

Furthermore, tactile material makes the learning process more enjoyable, creating an environment of cooperation and recognition of differences (Sá; Campos; Silva, 2007).

When designing activities, it is important for teachers to know the visual history of their students with VI, whether they have been blind since birth or have lost their sight throughout their lives, whether they still have any visual residue and to what extent this visual acuity can be taken into account in the classroom (Camargo, 2016).

The VI does not need significant adaptations to the curriculum, but they do need specific resources, time, modification of the environment, methodological and didactic procedures, as well as appropriate assessment. And the most important thing is that the content is dealt with in such a way that they can participate effectively in the activities, seeking to develop active attitudes in relation to the learning process, as well as a critical and reflective spirit (Santos; Galvão; Araújo, 2009).

In the absence of sight, information is assimilated through other sensory pathways. In the case of VI, the alternative ways of learning are mainly through touch and hearing (Bruno, 2006). Therefore, adaptations and technologies designed for blind people should be created with the possibilities of using the other senses at the forefront (Torres; Costa; Lourenço, 2016).

> Hearing, through language, is a fundamental sense for blind people, because much of what they can't see can be understood through language. To do this, they need sighted people to describe what is visual. However, as sighted people are less accustomed to perceiving the world through their other senses, this requires the blind to constantly 'adjust' what they know through their perceptions and what they know through the speech of those around them (Nunes; Lomônaco, 2008, p. 2).

Therefore, the lack of sight is not an impediment to development, it establishes different paths, since the acquisition of knowledge requires a different sensory systematization when compared to the sighted (Nunes; Lomônaco, 2008).

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2.2 The use of information and communication technologies (ICT) and Assistive Technology (AT) in chemistry teaching

For more than a decade, our country has seen a growing increase in technologies that seek to improve the lives of people with VI, promoting inclusion (Kastrup *et al*., 2009). Most of these technologies are based on the precepts of sensory exchange, in which touch and/or hearing are the main means of assimilating information in the absence of sight (Torres; Costa; Lourenço, 2016).

One tool used as a pedagogical resource for VIs is Assistive Technologies (AT)[2], since they include a wide range of instruments, systems, methods and practices applied to minimize the obstacles encountered by VIs. AT "covers all orders of human performance, from basic self-care tasks to the performance of professional activities" (Brasil, 2008b, p. 11).

ATs can be classified as Natural, Pegagogical, Technological and Cultural (Sganzerla; Geller, 2013). In this work, we have combined two types: pedagogical AT, in which we made tactile material with the aim of teaching content, and technological AT[3], in which we used a smartphone for audio lessons and exercises[4]. The pedagogical type of AT used in this work is considered low-tech, as it does not have electronic components in its composition, while the technological type of AT is high-tech, as it uses electronic components with a higher level of complexity (Cook; Hussey, 2012).

[2]The term assistive technology emerged in 1988 as an important legal element in American legislation, due to a need to establish legal regulations for the resources used by people with disabilities, in order to ensure a more independent, productive life and inclusion in the social context (Lavorato; Martinez; Mól, 2016).
[3] ATs can be low, medium or high-tech, varying in complexity based on the presence or absence of electronic components, as well as their availability on the market (Cook; Hussey, 2012).
[4] Screen readers are programs that interact with the cell phone's operating system, capturing any and all information presented in textual format and transforming it into a spoken response using a voice synthesizer. These programs make it possible to read elements and textual information contained on the device's screen, as well as providing audible feedback on what the user has typed. In this way, using remote controls and keyboard navigation, they enable the reading of menus, screens and texts (Lourenço *et al*., 2020).

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The use of AT can enrich the learning process of VI students, since the acquisition of knowledge helps them to stay in school and enables them to interact and participate in activities with other students (Frazão *et al*., 2020).

2.3 The conceptualization of Chemical Equilibrium (CE) and alternative conceptions presented by students

CE can be classified into three different models: the CE model focused on forces, the CE model focused on velocities and the CE model focused on energy (Prado, 2016). According to the author, in schools there is a predominance of discussion about CE based on the concepts of chemical kinetics. Therefore, in this work, we will focus on the kinetic approach.

A chemical reaction is a phenomenon related to the transformation of two or more substances. The initial elements are called reactants and the final compounds are called products. In addition to this reaction, there is also a reverse reaction, in which the products are able to react with each other to form the reactants. This type of reaction is called reversible[5] (Skoog *et al*., 2015; Oliveira; Silva; Tófani, 2009).

Kinetically, CE is a dynamic state in which the rate of change of reactants into products is equal to the rate of change of products into reactants. In this context, macroscopically, there is no apparent transformation of the system, but the direct and reverse reactions take place simultaneously at the same speed. However, at the submicroscopic level, the direct and reverse reactions continue to occur at equal speeds (Oliveira; Silva; Tófani, 2009; Santana, 2015).

Catalysts increase the speed of the reaction, causing the CE to be reached more quickly, by decreasing the activation energy in both the forward and reverse directions of the reaction. Consequently, the catalyst does not alter the equilibrium position or concentrations (Brown; Holme, 2015).

[5]Reversible reactions are expressed with a double arrow ($\rightleftharpoons$), indicating that the reactions occur in both directions (Skoog *et al*., 2015; Oliveira; Silva; Tófani, 2009).

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According to the "Law of Mass Action"[6], "the speed of the reaction is proportional to the concentrations in $mol.L^{-1}$ of the reactants raised to their stoichiometric coefficients" (Oliveira; Silva; Tófani, 2009, p. 3).

According to Santana (2015), the speed of a chemical reaction depends on two conditions: "i) the total number of collisions per unit of time between the particles (atoms, molecules or ions) of the chemical species taking part in the reaction, ii) the fraction of such collisions that effectively promotes the reaction" (p. 32).

Based on the equality of the speeds of direct and inverse reactions, the law of mass action establishes that, in the CE, the composition of the reaction can be expressed in terms of an equilibrium constant (K). For any reaction between gases, these can be treated as ideal (Atkins; Jones, 2007).

> The equilibrium constant is a mathematical expression considered to be an empirical relationship between the product and reactant concentrations, i.e. a direct ratio of the product concentrations and an inverse ratio of the reactant concentrations, with the respective stoichiometric coefficients as their powers. The concentrations used in an equilibrium constant are most often expressed in $mol\ L^{-1}$ (Oliveira; Silva; Tófani, 2009, p. 5).

Based on a generic chemical reaction, according to Atkins and Jones (2007):

$$aA + bB \rightleftharpoons cC + dD \quad (1)$$[7]

According to Oliveira, Silva and Tófani (2009), the speed of the direct reaction (2) can be represented by:

$$v_d = K_d [A]^a [B]^b \quad (2)$$

The speed of the reverse reaction (3) is expressed:

$$V_i = K_i [C]^c [D]^d \quad (3)$$

Based on the equality of reactions (2 and 3) and considering the law of mass action:

$$K_d [A]^a [B]^b = K_i [C]^c [D]^d \quad (4)$$

[6] The "Law of Mass Action" proposed by the Norwegians Peter Guldberg (chemist) and Cato Waage (mathematician) in 1867, states that the speed of a chemical reaction is proportional to the molar concentrations of the reactants (Atkins; Jones, 2007).
[7] The uppercase letters represent the substances and the lowercase letters represent the stoichiometric coefficients (Bettelheim *et al*., 2016, p. 199).

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$$K_{eq} = \frac{K_d}{K_i} \quad (5)$$

If all gases[8] are treated as ideal[9]:

$$K_{eq} = \frac{C^c D^d}{A^a B^b} \quad (6)$$

Equilibria in which all the species involved are in the same phase are called homogeneous equilibria (Chang; Goldsby, 2013). However, the concentration of a pure solid or liquid does not vary as the reaction proceeds (Brown; Holme, 2015). In other cases, substances in the equilibrium that are in different phases give rise to heterogeneous equilibria (Brown; Lemay; Bursten, 2005). Since the concentrations are constant, the liquid or solid reactants and products do not appear in K (Brown; Holme, 2015).

Once the CE has been established, only the variation in concentration, temperature and pressure can alter the position reached in this equilibrium. These qualitative effects caused by variations in the CE were studied by Le Chatelier[10] (Oliveira; Silva; Tófani, 2009, p. 11), and the scientist announced that:

> Any system in stable chemical equilibrium subjected to the influence of an external cause that tends to vary its temperature or condensation (pressure, concentration, number of molecules in a unit volume), in its entirety or only in some of its parts, undergoes only internal changes, which if they occurred in isolation, would cause a change in temperature or state of condensation of the opposite sign to that resulting from the external cause (Le Chatelier, 1884 apud Silva; Miranda; Franco-Patrocínio, 2022, p. 187)[11].

[8] "In molecular terms, a gas consists of a collection of molecules that are in incessant motion and that interact significantly with each other only when they collide with one another. The properties of gases were one of the first to be established quantitatively (largely during the 17th and 18th centuries), when the technological demands of balloon travel stimulated their investigation" (Atkins; Paula, 2017, p. 29).

[9] "In an ideal system, the interactions between the molecules in a mixture are all equal. The ideal gas equation (PV=nRT) is a summary of three empirical conclusions, namely Boyle's law ($p \propto 1/V$ at constant temperature and number of moles), Charles' law ($p \propto T$ at constant volume and number of moles) and Avogadro's principle ($V \propto n$ at constant temperature and pressure)" (Atkins; Paula, 2017, p. 6).

[10] The Le Chatelier Principle, also known as the Le Chatelier-Braun Principle, was formulated by French chemist Henri Louis Le Chatelier (1850 - 1936) in 1884. Le Chatelier based himself on the work of J. H. van't Hoff (1852 - 1911) and the ideas of G. Lippmann (1845 - 1921) when studying the evolution of systems in equilibrium due to changes in temperature (Canzian; Maximiano, 2010).

[11] Original French translation: "Tout système en equilibre chimique stable soumis à l'influence d'une cause extérieure qui tend à faire varier soit sa température, soit sa condensation (pression, concentracion, nombre de molécules dans l'unité de volume) das sa totalité ou seulement dans qualquesunes de ses parties, ne peut éprouver que des modifications intérieures, qui, se elles se produisaient seules, amèneraient un

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Le Chatelier's Principle can be expressed as follows: "When a system in equilibrium undergoes a disturbance, it responds in such a way as to minimize the effect of the disturbance" (Atkins; Paula, 2017, p. 254). In other words, a new state of CE will be reached.

In short, the study of CE is often considered problematic for teaching and learning by researchers and teachers, since students tend to assimilate the concept from their previous knowledge and everyday life, thus giving rise to alternative conceptions (Santos; Melo, 2012). In a study published by Silva, Miranda and Franco-Patrocínio (2022), the authors carried out a survey of publications from 2001 to 2021. In this analysis, it was possible to see what the trends were in publications on this subject.

Dealing more specifically with alternative conceptions, the authors summarized the most recurrent, the seven main ones being: the visualization of systems in equilibrium as compartmentalized; the reversibility of the reaction, the reverse reaction would only start when the direct reaction ended; the idea that equilibrium is not dynamic, that is, it would be a static equilibrium; the conception that the concentration of reactants and products are equal in equilibrium; the increase in concentration of reactants would cause an increase in the speed of the direct reaction and, consequently, the concentration of products would increase; the difficulty of understanding the effect of the catalyst. and, finally, the belief that if there were changes in the equilibrium condition, the speed of the direct reaction would increase, consequently, the speed of the inverse reaction would have to decrease and vice versa (Silva; Miranda; Franco-Patrocínio, 2022).

So, thinking about students' difficulties with the content of CE, and how learning can be facilitated by the use of ICTs, we developed the didactic proposal for this subject of Chemistry.

3 Methodology

changement de température ou de condensation de signe contraire à celui résultant de la cause extéuriere." (Le Chatelier, 1884, p. 187 *apud* SiLva; Miranda; Franco-Patrocínio, 2022, p. 7).

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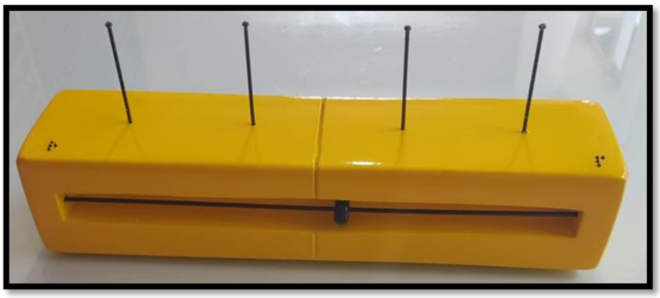
The tactile materials proposed in this study are intended to promote the more effective participation of blind students in chemistry classes, more specifically in the subject of CE. Therefore, two tactile objects were made, called Model for Chemical Equilibrium 1 (MCE1) and Model for Chemical Equilibrium 2 (MCE2). These models were designed to illustrate how the variation in concentration influences CE.

MCE1 was designed to help teachers in CE classes, covering both blind and sighted students, i.e. working from an inclusive perspective. MCE2, on the other hand, was produced so that the blind student can take it to non-school locations, so that the student can carry out study activities independently and in an out-of-class environment.

Thinking about the choice of materials, the tactile material should not present a risk to the blind student. That said, to build the materials, we used pieces of wood, a bicycle spoke, smooth-textured black and red beads, rivets, dowels, nuts, yellow and black paint, a straightedge, a punch and 3D glue.

MCE1 is robust, with dimensions of 27.50cm x 5.50cm. It is light and has an intense yellow color. Along its length, it has four black-painted rivulets representing the components of a chemical equation. It has a central hole and, at the ends, the initials in Braille of the words "reactant" and "product", helping blind students to delimit the parts that represent a chemical equation. In the width of the material, in the middle, there is an opening made up of a bicycle spoke and a black moving bead attached to the ends of the equipment, as shown in Figure 1.

Figure 1: Photograph of MCE1



Source: Authors' collection

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In the products (represented by the right side of the figure), the last rivet is removable, allowing it to be removed in the case of a synthesis reaction[12].

MCE2 is small, measuring 14.00cm x 8.50cm, and made of wood. Along its length, there are four thick gray rivets and a white bead in the middle, which marks out the reactants and products. In addition, the sides have different shapes so that the blind student can differentiate between the members of the chemical equation. The width contains a gray bicycle spoke and a beige moving pin. See Figure 2 below.

Figure 2: Photograph of MCE2

Source: Elaborated by the authors

3.1 Presentation of the Educational Product

In order to help the reader understand, we tried to explain the usability of the tactile material using an example.

Analyzing carbonated water (Figure 3), which has a slightly bitter taste due to the presence of carbon dioxide (CO2):

[12] The synthesis reaction is when two or more reactants transform into a single product (Skoog *et al*., 2015; OlIveira; Silva; Tófani, 2009).

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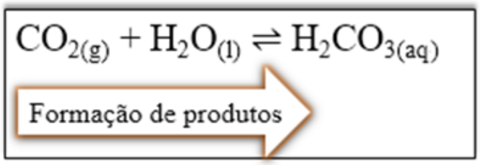
Figure 3: Chemical equation

$$CO_{2(g)} + H_2O_{(l)} \rightleftharpoons H_2CO_{3(aq)}$$

Source: Elaborated by the authors

To maintain the equilibrium of the reaction, by increasing the concentration of carbon dioxide (CO_2) in the reaction, the system eases the disturbance by forming more products, i.e. by increasing the concentration of carbonic acid (H_2CO_3) and consuming carbon dioxide (CO_2). Therefore, the CE shifts to the right, i.e. an increase in the concentration of one of the reactants causes the equilibrium to shift towards the formation of more products. See Figure 4 below.

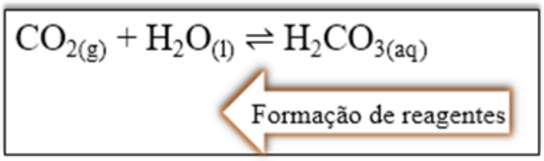
Figure 4: CE shift favoring product formation



Source: Elaborated by the authors

On the other hand, by increasing the concentration of carbonic acid, the system mitigates the disturbance by increasing the concentration of reactants, as shown in Figure 5.

Figure 5: CE shift favoring the formation of reagents



Source: Elaborated by the authors

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Bringing the example to the tactile material, we have that the black beads represented in MCE1 and the nuts depicted in MCE2 correspond, respectively, to the fixed molar ratios of the chemical compounds, as can be seen in Figure 6 below.

Figure 6: MCE1 and MCE2 representing the molar ratios of the components of the chemical reaction exemplified

Source: Authors' collection

Increasing the concentration of CO_2, represented by the red bead in MCE1 and the addition of a nut in MCE2, tends to form more H_2CO_3, shifting the equilibrium to the right, depicted by the black bead and the beige peg on the front of the tactile materials in Figure 7.

Figure 7: Example in MCE1 and MCE2 of the increase in compound concentration and shift of the CE to the right

Source: Authors' collection

The reverse reaction also occurs, as shown in Figure 8 below:

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Figure 8: Example in MCE1 and MCE2 of the increase in compound concentration and the shift of the CE to the left

Source: Authors' collection

In this way, the blind student can add or remove beads/nuts as necessary. Once they have added the beads/nuts, they will be able to see how the CE is moving and then use the front of the MCE to show how it is moving.

It's important to emphasize that tactile material does not replace the teacher. We believe that teacher mediation is extremely important for a correct understanding of the content, mainly because tactile material is not capable of minimizing all alternative conceptions - such as the idea that CE is compartmentalized. Therefore, the teacher's intervention is essential to explain the phenomenon and deconstruct any misconceptions on the part of the student.

3.2 O aplicativo para celular

Through the *GoodBarber*[13] platform, we adapted an application called "Estudaki". It's available on the *Google Play Store*[14] and can be accessed on Android devices.

Once the software has been downloaded to the device, there is no need to log in. The app's[15] menu includes podcast, form, form template and terms and consent policy[16].

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[13] GoodBarber offers the technology to easily adapt an application, without technical knowledge.

[14] Digital content distribution service for the Android system.

[15] To download the app on your cell phone, follow this link: https://play.google.com/store/apps/details?id=com.goodbarber.estudaki.

[16] The app's consent form and privacy policy are written in English, due to Google Play Store regulations.

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To help manipulate the app, the blind student will need to activate *TalkBack*[17], available in the phone's settings. After turning on this device, the function will be represented by a "dummy" highlighted in red in the bottom right-hand corner, as shown in Figure 9.

The app also has three audio lessons in podcast format on the content of CE. Students can listen to them at the touch of a button.

Figure 9: Screenshots of the application showing accessibility and audio lessons

Source: Elaborated by the authors

The form contains eighteen multiple-choice questions from the National High School Exam (ENEM) and university entrance exams, referring to the content of CE displacement due to the effect of changing the concentration of substances.

[17] An accessibility feature that provides an audible response so that the user can navigate the device without looking at the screen (Silva *et al*., 2023). By tapping TalkBack and sliding your fingers across the screen, the program scrolls through texts and phrases and synthesizes a male or female voice. To deactivate it, you can press and hold the two volume keys for a few seconds.

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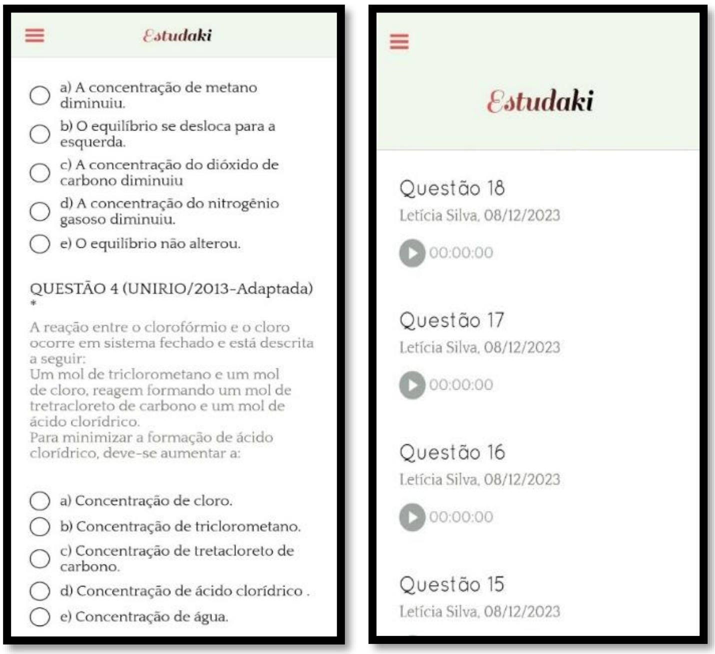
So that the VI student can access the answers to the questions on the form, they have been recorded and made available in the template menu[18].

Figure 10: Example of the questions on the form and the form's answer sheet



Source: Elaborated by the authors

3.3 Audio lessons

The audio lessons[19] were recorded and made available on the Estudaki app. Students will be able to listen to the lessons when questions arise and carry out the activities in an out-of-class environment.

These audio classes were designed to complement the lessons given by the lecturer. It's a way for students to remember the most important concepts before doing the exercises.

[18] The audios can be listened to on the app, or via the link: https://drive.google.com/drive/folders/1pnOEt-jY-A0wCCAdyN4LOiy0ZfWY_5Ve?usp=sharing.

[19] The audio lessons can be listened to in the application tab, as shown in Figure 9, or via the link: https://drive.google.com/drive/folders/1WUumXhrg_sdASb3GksY4rF-3dkhGwkk-?usp=sharing.

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Regarding the organization of the content of the audio lessons, the first lesson covered the concept of a chemical reaction, the representation of chemical reactions, reversible and irreversible reactions and the factors that influence the reversibility process. In the second lesson, we explained the speed of a chemical reaction and the concept of CE. To finalize the content, we presented Le Chatelier's principle and the factors that alter the CE.

Another point to highlight is the control the student has over the audios, making it possible to pause, rewind and/or fast-forward when it suits them.

Exercises

Eighteen adapted multiple-choice[20] questions have been made available on the form tab of the "Estudaki" application from ENEM and university entrance exams. The chemical reactions presented in the exercises have been described so that TalkBack can read them correctly.

The exercises provided allow blind students to assess whether they are managing to complete the exercises in accordance with the content studied. In this way, they will have a diagnosis of their learning in relation to this content. In order to carry out these exercises, the blind student must use tactile material to help them complete the task.

In view of the above, the educational product we have developed enables blind students to study the content of CE independently, using audio lessons and developing retention exercises with the aid of tactile material and a smartphone. With this Educational Product, we aim to contribute to the blind student's out-of-class studies, generating autonomy. In addition, we believe that the didactic material can be used in a regular classroom context, with the active participation of all the students in the class.

4 Conclusions

[20] Multiple-choice questions contain a statement and possible answers. The student chooses the option they think answers the problem.

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The development of the Educational Product on CE for blind students emerges as an initiative in the quest to contribute to the realization of inclusive education. We believe that the use of tactile material and auditory approaches, based on the app, can favor students' understanding of concepts related to CE.

We created tactile material on the subject of CE that allows students to touch and manipulate. We believe that the tactile object proposal enables blind students to expand their knowledge, promote autonomy, stimulate and facilitate the learning process for those who do not have access to visual information.

In addition to the tactile object, this work includes the "Estudaki" app, which contains audio lessons on the content, exercises on CE displacement and audios with the answers to the questions. The app allows you to study outside of class, promoting more independent study of the subject in question.

We know that the proposal made here is just one topic among many other possibilities in chemistry. However, we understand that, from this work, others may emerge, improving our proposal.

The importance of inclusion is not just limited to access to information, but also extends to the active and meaningful participation of students in the teaching and learning process. In this context, the purpose of this study is not only to help fill gaps in blind students' learning, but also to enrich the educational environment as a whole, helping to promote diversity and equal opportunities.

We recognize that there are still many challenges to overcome, and the constant adaptation and improvement of strategies is fundamental. Continued commitment to creating accessible educational environments is essential to ensure that all students, regardless of their conditions, have access to scientific knowledge and participate fully in the construction of knowledge.

This study reinforces the idea that inclusion is not just a question of physical accessibility, but a profound transformation in the way we conceive and implement education. By recognizing and responding to the diverse needs of students, we contribute

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to a fairer and more equitable society, in which everyone has the opportunity to reach their full potential.

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