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Teaching Thermochemistry to students with visual impairments from an inclusive perspective: in the face of teachers' difficulties

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Abstract: The present study aimed to identify the difficulties in adapting classes in teaching thermochemistry from an inclusive perspective. This study was developed with the collaboration of four Chemistry teachers from the second year of high school who teach classes for students with visual impairments. The methodology used was descriptive and field, involving observations and interviews with individuals with practical experience in the area studied. The data were analyzed qualitatively, using content analysis by Bardin (2016). The results of this work lead us to conclude that the Chemistry teachers participating in this study do not feel prepared to work with students with visual impairments, and the responses obtained The interviews carried out showed numerous challenges and difficulties in relation to teaching thermochemistry to this group of students, such as the lack of practical training, which is often non-existent during graduation and the lack of construction and/or adaptation of accessible and tactile tools for teaching this content.

Keywords*:* Inclusion. Teaching Thermochemistry. Chemistry Teachers. Visual Impairmen.

Enseñar Termoquímica a estudiantes con discapacidad visual desde una perspectiva inclusiva: ante las dificultades de los docentes

Resumen**:** El presente estudio tuvo como objetivo identificar las dificultades en la adaptación de las clases en la enseñanza de la termoquímica desde una perspectiva inclusiva. Este estudio se desarrolló con la colaboración de cuatro profesores de Química del segundo año de secundaria que imparten clases para estudiantes con discapacidad visual. La metodología utilizada fue descriptiva y de campo, involucrando observaciones y entrevistas a personas con experiencia práctica en el área estudiada. Los datos fueron analizados cualitativamente, mediante el análisis de contenido de Bardin (2016), los resultados de este trabajo nos llevan a concluir que los docentes de Química participantes en este estudio no se sienten preparados para trabajar con estudiantes con discapacidad visual, y las respuestas obtenidas en las entrevistas Los trabajos realizados mostraron numerosos desafíos y dificultades en relación con la enseñanza de la termoquímica a este grupo de estudiantes, como la falta de formación práctica, muchas veces inexistente durante la graduación y la falta de construcción y/o adaptación de herramientas accesibles y táctiles para la enseñanza. Este contenido.

Palabras clave: Inclusión. Enseñanza de Termoquímica. Profesores de Química.

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Discapacidad Visual.

Ensino de Termoquímica para alunos com deficiência visual numa perspectiva inclusiva: face às dificuldades dos professores

Resumo: O presente estudo objetivou identificar as dificuldades para adaptação das aulas no ensino de termoquímica numa perspectiva inclusiva. Este estudo foi desenvolvido com a colaboração de quatro professores de Química da segunda série do Ensino Médio que ministram aulas para alunos com deficiência visual. A metodologia empregada foi descritiva e de campo, envolvendo observações e entrevistas com indivíduos com experiência prática na área estudada. Os dados foram analisados qualitativamente, utilizando a análise de conteúdo de Bardin (2016).Os resultados deste trabalho levam-nos a concluir que os professores de Química participantes deste estudo não se sentem preparados para atuarem com alunos com deficiência visual, e as respostas obtidas nas entrevistas realizadas mostraram inúmeros desafios e dificuldades em relação ao ensino de termoquímica para este público de alunos, tais como a ausência de uma formação prática e, muitas vezes, inexistente durante a graduação, e a falta construção e/ou adaptação de recursos pedagógicos acessíveis e táteis para o ensino desse conteúdo.

Palavras-chave: Inclusão. Ensino de Termoquímica. Professores de Química. Deficiência Visual.

1 Introduction[4]

As far as school education is concerned, access for visually impaired students in basic education has been endorsed by the enactment of civil and educational laws in Brazil, such as the Education Guidelines and Bases Law (LDB) No. 9.394/96 and the Brazilian Inclusion Law (LBI) No. 13.146/15. In these norms, with regard to the right to education and the duty to educate, the learning process is highlighted as a right for all and the guarantee of access and permanence in school, regardless of the individual's physical, social and cultural characteristics.

From this perspective - of an inclusive school - the student must be seen as the central focus of the teaching and learning process in which they can develop and build the skills necessary for their autonomy and the creation of relationships between all those involved. However, inclusive education is still considered a major challenge to be overcome by educational institutions, as it is clear that many teachers are unprepared and that there is a lack of assistive technologies for teaching students with disabilities.

When examining the current educational scenario, it is possible to see that,

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despite the fact that visually impaired students are included in regular classes, there are still numerous obstacles in this process. Among these challenges are the lack of a suitable physical environment and the poor training of teachers to support and care for students, given that the teacher's preparation goes far beyond studying a specific subject.

These facts become even more challenging when we refer to the teaching of chemistry and, in particular, the subject of thermochemistry, since it is an area with largely abstract content, linked to visual stimuli and which uses its own language, with formulas, chemical equations and symbologies that are essential to its learning. Therefore, the poor training of chemistry teachers to work with these students in regular classes is a serious problem when it comes to implementing inclusive schools. In view of the above, the question arises: what difficulties do chemistry teachers have in adapting lessons to teach thermochemistry from an inclusive perspective?

For students with or without some kind of visual impairment, many chemical contents are considered difficult to understand, especially those that require the macroscopic, microscopic and representational levels of matter. From this perspective, Benite et al (2016) emphasize that chemistry is a science composed of its own language, produced through a complex interpretation and description of the various transformations of matter. It is based on mathematical models, codes and reactions that are made up of laws, formulas, equations and graphs, which indicates a massive visual character.

In this way, understanding chemical content requires an understanding and signification of concepts and symbolic representations. Thus, Andrade and Maldaner (2011, p. 9) point out that chemistry "is made up of a system of pre-established signs, created in a social group [...] a conceptual system formed by networks of generalizations that provide answers, or worldviews, which serve to explain things in the world". Having said this, Ormelezi (2000) points out that the understanding and meaning of concepts comes about through a complex process of abstraction and generalizations of experiences, which are conquered and defined in the cognitive structure to portray reality. Thus, concepts enable communication between individuals through representations of signs and also allow abstract ideas to be obtained when it is not possible to have concrete experience.

In view of this, visually impaired students encounter challenges during the

learning process, such as difficulties in development and interaction with the environment. However, these individuals are capable of constructing meanings through social relationships, experiencing experiences and categorizing concepts and materials they come into contact with. Thus, in order to promote the understanding of visually impaired students in chemistry teaching, it is necessary for teachers to be able to adapt and/or build assistive technologies to bring students closer to these conceptions.

Therefore, the use of assistive technology in the process of acquiring knowledge for visually impaired students as a tool allows "different sensations with the remaining senses accompanied by symbolic mediation negotiated by the teacher, aiming at (re)interpretations of the information felt in the phenomena" (Benite et al., 2017, p.97). In this way, the use of these resources in the teaching of chemical content from an inclusive perspective favors the development and construction of meanings, processes of signification and autonomy for these students.

With this in mind, the purpose of this study was to identify the difficulties encountered by chemistry teachers in the Alagoas state education system, specifically in the city of Arapiraca, in adapting thermochemistry lessons in an inclusive way. To this end, four teachers were interviewed who discussed their conceptions of inclusive education and inclusive thermochemistry teaching, shared the difficulties encountered and proposed actions that could contribute to the training of chemistry teachers in teaching visually impaired students.

2 Visual impairment: concepts, definitions and characteristics

The characterization of visual impairment analyzed in this study involves two types: blindness and low vision. It is necessary to present some concepts proposed by different authors in relation to what visual impairment is, as well as its characteristics.

There is no uniform definition of disability, whether in the medical field, the rehabilitation field or elsewhere. In this context, in recent publications, Haddad et al. (2015) emphasize the importance and need for conformity of terms, concepts and definitions in the field of visual impairment, since the presence of different classifications hinders the process of communication and exchange of information between numerous professionals, as well as between visually impaired individuals themselves.

Until the mid-1980s, visual impairment was defined by assessing visual acuity. According to Martín and Ramírez (2003), during this same period, the World Health Organization (WHO) proposed that the classification of visual impairments should be based on the measurement of visual acuity and the amplitude of the visual field.

In this context, visual acuity is understood as the ability of the eyes to distinguish high-contrast details, i.e. to recognize the shape and contour of objects and symbols or images. The measurement of acuity is represented by a fraction in which the numerator refers to the distance of identification of the object, and the denominator corresponds to the size of the visualized optotype. The visual field is defined as the entire area covered by vision, under normal conditions of around 180º, with the eyes and head remaining static.

Visual impairment is the permanent loss or reduction of visual capacity in both eyes that cannot be improved or corrected with the use of lenses, clinical or surgical treatment. (Prado, 2013).

Visual impairment covers three main categories: blindness, amblyopia and monocular vision. Blindness can be congenital, resulting from hereditary factors, or acquired, caused by accidents, diseases, vitamin A deficiencies and other elements. According to Garcia (2014), congenital blindness is characterized by visual impairment that is present at birth or occurs up to the age of 5, while acquired blindness manifests itself after this age.

The International Statistical Classification of Diseases and Related Health Problems (ICD-10) categorizes visual impairment as follows: blindness is considered when visual acuity is less than 0.05 or if the visual field is less than 10º; amblyopia is considered when visual acuity in the better eye, even after correction, is less than 0.3 and greater than or equal to 0.05 and/or if the visual field is less than 20º (Haddad et al. 2015).

In this respect, Decree No. 5.296 of 2004, of the Brazilian legislation, defines visual impairment as:

> Art. 5 - For the purposes of this Decree:
>
> c) visual impairment: blindness, in which visual acuity is equal to or less than 0.05 in the better eye, with the best optical correction; low vision, which means visual acuity between 0.3 and 0.05 in the better eye, with the best optical

> correction; cases in which the sum of the visual field measurement in both eyes is equal to or less than 60°; or the simultaneous occurrence of any of the previous conditions (BRASIL, 2004, p. 2).

On the other hand, blindness can also be defined, according to Sá, Campos and Silva, as: a serious or total alteration of one or more of the elementary functions of vision that irreparably affects the ability to perceive color, size, distance, shape, position or movement in a more or less comprehensive field. It can occur from birth (congenital blindness), or later (adventitious blindness, known as acquired blindness) as a result of organic or accidental causes (Sá, Campos e Silva, 2007, p.15).

According to the Saberes e Práticas da Inclusão (Knowledge and Practices of Inclusion) collection by the Secretariat of Special Education - SEESP/MEC (2006), amblyopia is an alteration in the functional capacity of vision, which can be caused by various isolated or related factors, namely: significant low visual acuity, reduced visual field and variations in contrast sensitivity that affect or restrict the individual's visual performance. Amblyopia, also known as low vision, is characterized by a person's ability to see between 20/40 and 20/200 after treatment.

By contrast, an individual considered to have normal vision has a vision capacity of 20/20. Among the category of people with amblyopia, there are also variations: some can read certain printed material if it is of a considerable size or is close to their eyes, while others can only identify large shapes, colors or contrasts (Sonza, 2004).

Monocular vision, in turn, refers to the ability to see with only one eye (Brasil, 2021). This condition can be caused by different reasons, such as loss of vision in one eye due to injury or disease, as well as congenital or caused problems affecting only one eye.

When we analyze the conceptions of the authors mentioned above, we see that visually impaired people are individuals who have some alteration in their vision or a reduction in visual acuity, which impairs the performance of their vision. This condition is characterized by the absence of visual perception caused by various factors, such as physiological, neurological, congenital or even those caused accidentally.

3 Inclusion of disabled students in the school context

Education's central challenge is to promote the development of knowledge for those who find themselves in Plato's allegorical "cave", in which individuals have a

distorted view of reality, believing only in representations created by culture and information acquired throughout life. The myth of the cave highlights the importance of freeing oneself from the cultural and social dominations of the world in order to achieve a true understanding of reality. From this perspective, Inclusive Education is a necessary educational innovation to minimize prejudices, eliminate paradigms and encourage diversity within the school environment.

In this vein, inclusive educational practice has shown a change in individuals' thinking and attitudes towards people with disabilities. From this perspective, the school environment contributes to the creation of affective relationships, to learning and to the development of the student, favoring a change in attitudes and mentalities in order to build critical and inclusive thinking. Díaz *et al.* (2009, p. 255) characterize the school as:

> It's a space where different actors coexist, not only in the school, but also outside it, in contexts involving the school community, the family and other social groups. As learners, teachers, students, school staff and family members will live together and jointly build the daily life of the school, each and every one at the same time leaving their personal and collective mark.

Based on the above, it is essential to build an inclusive school, making it a space open to students with disabilities. As such, the relationships established in this environment ensure that these individuals become citizens prepared to face the challenges and obstacles imposed by contemporary society. Accordingly, Rodrigues (2006, p. 196) states that,

> inclusion comes from the fact that it demands a change in the educational paradigm [...]. In the inclusive perspective, the subdivision of school systems into special education and regular education modalities is abolished. Schools cater for differences without discriminating, without working separately with some students, without establishing specific rules for planning, learning and assessment (curricula, activities, learning assessment for students with disabilities and special educational needs).

Within this context, Minetto (2008, p.19) states that education is "responsible for socialization, which is the possibility of a person living in society with quality of life; it therefore enables the integration of the individual with the environment, with an accentuated cultural character". Therefore, educational institutions direct people towards life in society, making it possible to explore new cultures, enabling students to face the barrier of prejudice and get to know the diversity that exists around them.

In line with the above, inclusion is a significant challenge for education. However, the Salamanca Declaration, the result of a world conference held in Spain in 1994, proposes a perspective of education for all, not just for those with special educational needs, as shown in the following excerpt:

> Schools should welcome all children, regardless of their physical, intellectual, social, emotional, linguistic or other conditions. They should welcome children with disabilities and gifted children; street and working children; children from remote or nomadic populations; children from linguistic, ethnic or cultural minorities and children from other disadvantaged or marginalized groups or areas (Unesco, 1994, p. 3).

In view of this, it is noteworthy that the Salamanca Declaration advocates that all students should have the opportunity to learn and study together, regardless of their abilities, knowledge, physical and social conditions. In this way, this document represented a significant step forward in drawing the attention of governments to invest in improving schools so that they can serve students without distinction. In addition, this declaration is considered an important milestone, as it provides crucial guidelines for the consolidation of public policies aimed at inclusion in various countries.

Through this document, inclusion in Brazilian schools has made great contributions, such as in the Federal Constitution (1988), which specifies, in its Article 205, inclusion as a principle of the right of people with disabilities in the social and school spheres:

> Education, the right of all and the duty of the state and the family, will be promoted and encouraged with the collaboration of society. Aiming at the full development of the person, their preparation for the exercise of citizenship and their qualification for work (Brasil, 2017, p. 123).

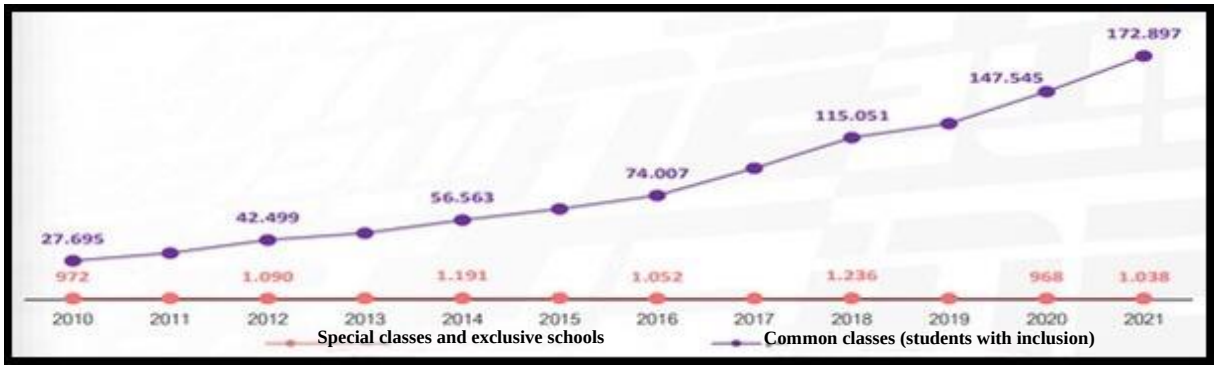
The Brazilian Law for the Inclusion of People with Disabilities (LBI), known as the Statute for People with Disabilities, is an important achievement in the quest for social inclusion and citizenship for people with disabilities. The aim of this law is to ensure and promote, on equal terms, the exercise of fundamental rights and freedoms by people with disabilities. According to Chapter IV and Article 27 of the LBI, the right to education for people with disabilities is emphasized:

> Education is the right of people with disabilities, ensuring an inclusive education system at all levels and lifelong learning, in order to achieve the maximum possible development of their physical, sensory, intellectual and social talents and abilities, according to their characteristics, interests and

learning needs (Brasil, 2015, p. 6).

Under this assumption, educational institutions have an obligation, in the same way as they do for other students, to ensure that visually impaired students remain in and have access to regular classes, respecting their rights and duties and valuing the differences of each student. The graph below highlights the evolution in the number of people with disabilities enrolled in secondary education in Brazilian schools over the last 10 (ten) years.

Graph 1: Enrollment of people with disabilities in secondary education in basic education



Source: INEP/SCHOOL CENSUS 2021, (Brasil, 2022)

Based on data from the Basic Education School Census, published by the National Institute of Educational Studies and Research Anísio Teixeira of the Ministry of Education - MEC (2022), referring to the year 2021, it is possible to ascertain, as shown in Graph 1, an evolution in the enrollment of students with disabilities in high school in ordinary schools, increasing from 27,695 in 2010 to 172,287 in 2021, however, the number of enrollments in schools with special classes or exclusive schools remained constant over the same period.

It is important to highlight the significant growth in the rate of inclusion of disabled students in regular classes over the last 10 years. This data shows that discussions about inclusive practices and those related to disability in schools are bringing about important changes in legislation, educational practices and curricula, enabling these students to remain in school and be independent.

4 Teaching chemistry and visually impaired students

Chemistry is an exact science, that is, a branch of human knowledge that aims to study matter and its transformations, properties, changes and phenomena that are occurring in our surroundings and in everyday activities. For this reason, this science

provides numerous advantages and benefits for the development of the lives of all human beings (Brown et al., 2016).

Thus, the purpose of teaching chemistry is not only to transmit theoretical content to students, but also to train students with the ability to observe, investigate, understand, analyze and, above all, to ask questions about the processes and problems that occur around them. The purpose of this teaching is proposed in the National Curriculum Parameters for Secondary Education (PCNEM):

> The knowledge disseminated in chemistry teaching allows for the construction of a more articulated and less fragmented view of the world, helping individuals to see themselves as participants in a world in constant transformation (Brasil, 1999, p.32).

However, when it comes to teaching chemistry, especially in high school, it is difficult for students to learn certain subjects covered in the classroom. This is because this subject requires students to have a high level of abstraction, since part of what is studied is based on representational models of something that cannot even be visualized.

In this vein, Gomes and Mortimer (2008) point out that chemistry teaching should cover three distinct levels of approach: the first level is macroscopic, which refers to observable phenomena; the second level is theoretical or microscopic, which relates to explanations based on abstract models, such as the concept of atoms, ions and molecules; and the third level is representational or symbolic, which deals with the representation of substances and transformations through symbols, chemical equations, tables, graphs and other resources.

Chemistry is a curricular component that often requires a high degree of abstraction for numerous pieces of content, as well as for the production of ideas and the association and articulation of concepts, which often becomes a challenge for the learning process and the development of students' various skills. In view of this, the teaching and learning process is challenging for both teachers and students, as Benite et al. point out:

> Chemistry has its own language, created from the complex interpretation and description of natural phenomena and transformations of materials and substances. It is based on mathematical models and reactions, and is represented by equations, formulas, graphs and so on. Thus, studying chemistry requires understanding and giving meaning to these symbolic

> representations, valuing the students' context as a means of problematizing knowledge (Benite et al., 2016, p. 3).

Under this logic, teaching chemistry using these three fundamental levels proposed by Gomes and Mortimer (2008) and considering the challenges listed by Benite et al. (2016) is a major obstacle for teachers, since these aspects become a little more complex when there is a visually impaired student in the classroom, due to the association and articulation of concepts, the extensive use of graphs, equations and other representations that favor the explanation of chemical knowledge. In this context, Beltramin and Góis (2012) also emphasize that:

> In the case of the blind, there is a big barrier because chemistry is an area of knowledge that depends on visualization, both of macroscopic phenomena and of representations of structures and transformations. Visual communication is the basis of different means of communication in society, and in the case of chemistry, there is a great dependence on formulas, symbols and specific codes (p. 3).

Pires, Raposo and Mol (2007) also claim that teaching chemistry to visually impaired students is complex, since, as much as teachers strive to contribute to the process of inclusion and learning of these students, they have few publications and resources adapted for students with this specificity. In addition, there is another problem regarding the initial and continuing training of chemistry teachers in teaching visually impaired students.

Machado (2018) reinforces and highlights other reasons and challenges that make it difficult to teach chemistry to visually impaired students:

> With regard to teaching chemistry to people with visual impairments, the literature shows that neither the teachers are sufficiently trained, nor the educational structures have the necessary accessibility so as not to isolate the disabled. In the case of visually impaired students, this is one of the biggest challenges in education, because in addition to not being able to see the subject, the teacher needs to arouse interest in the student, finding a methodology that can reach the content covered (p.12).

It is therefore essential to adopt new strategies and technologies to facilitate the learning of chemical content by visually impaired students. The adaptation of teaching materials and the use of assistive technologies (AT), such as tables, graphs and diagrams, are fundamental to minimizing barriers and promoting the inclusion of these students in the school environment. Furthermore, it is important to emphasize the need for better initial and continuing training for teachers, enabling them to deal with the

diversity present in the classroom.

5 Chemistry teacher training in the context of Inclusive Education

Teacher training has now been widely recognized as an important factor in improving the quality of education around the world. This is due to the fact that teacher training provides an opportunity for all those involved in education to discuss and improve the quality of teaching, with the aim of promoting a process of constant qualification.

According to Gati *et al*. (2019), in order to build a quality, equitable and inclusive education system, it is necessary to implement teacher appreciation policies that provide an enthusiasm for the profession, initial and continuing training, as well as professional development, adequate remuneration and excellent working conditions.

It is in this reality that it is essential to understand the importance of teacher training for their teaching practice in the face of the current reality, since improved knowledge will allow for a more efficient pedagogical experience that meets the school's objectives and facilitates the teaching and learning process. According to Nóvoa (1997), teacher qualifications are essential to strengthen the care of students and the conviction that students have the potential to develop new skills. This becomes even more relevant in a context where quality education is seen as one of the pillars for the growth of society.

The proposal for guidelines for the training of basic education teachers highlights the importance of the educator's role in the current conception of education, in which the main point is training for the development of citizenship. Among the roles required of teachers, one stands out: assuming and knowing how to deal with the diversity that exists among students (Brasil, 2002).

In the context of chemistry teaching, training teachers to meet the principles of Inclusive Education and deal with diversity in the classroom is still a major challenge. Authors such as Pedroso, Campos and Duarte (2013) and Paula, Guimarães and Silva (2018) stress the importance of training chemistry teachers in an inclusive way, with the aim of developing a critical and sensitive eye for the heterogeneity of students and building effective pedagogical practices in the teaching and learning process. From this perspective, Vilela-Ribeiro and Benite (2010) reiterate that:

> It is necessary to consider teacher training for Inclusive Education as an integral part of the general training process, and not as an appendix to their studies or a supplement. What's more, it's important that teachers acquire a critical view of the subject, as they will be responsible for selecting the curriculum in schools and will have to adapt the content, assessment practices and teaching and learning activities. So, for us to have a paradigm shift in Inclusive Education, the first thing to change is the teacher (p. 587).

In this respect, Paula, Guimarães and Silva (2017) state that the training of these educators needs to cover aspects that qualify teachers to teach in the face of the heterogeneity of students and include them, respecting diversity. In this way, it responds to the training requirements that arise in the face of the needs of Inclusive Education, training and enabling teachers to work in the face of this reality. From the perspective of training chemistry teachers for Inclusive Education, the training needs are related to:

> [...] essential knowledge and skills to include students, regardless of their needs, which generally involves: knowing the purposes of Inclusive Education, knowing about the student's disability, knowing how to make the curriculum more flexible; knowing how to evaluate, knowing the political and historical aspects of Inclusive Education and knowing how to work as a team (Paula, Guimarães and Silva, 2017).

Considering this context, the training of chemistry teachers requires that, in addition to specific knowledge, graduates also acquire didactic-pedagogical skills in order to deal with diversity and provide meaningful learning alternatives for their students. These perspectives also need to be developed in the area of Inclusive Education, since these teachers will need to be qualified for the heterogeneity of classrooms.

Oliveira (2014) also reiterates that teacher training, in the teaching and learning process for people with visual impairments, must understand inclusive education with a focus on special education, in other words, enabling everyone to participate without any form of distinction and presenting chemistry teaching as an educational process for individuals with visual impairments, so that they can practice their rights and duties before society on an equal basis.

Thus, in Inclusive Education, teachers play an important role, since they have the power to reduce differences in the classroom and encourage active and critical participation by students as authors of their own learning process. However, without adequate training for these professionals, the application of methodologies, strategies,

didactic and pedagogical resources may not be enough to guarantee an effective teaching and learning process for the students.

6 Methodological Procedure

In order to achieve the initial objective, this work was descriptive and field-based, as it involved observations and interviews with people who had practical experience of the problem being researched.

In this context, Prodanov and Freitas (2013) point out that descriptive research is carried out by recording and describing the observed fact without the researcher's interference. On the other hand, the aim is to identify the frequency of the event, its nature, characteristics, causes and relationships with other cases. To collect data, we used specific techniques such as interviews, forms, questionnaires and observation.

Field research, according to Marconi and Lakatos (2017), is applied in order to obtain information and/or knowledge in relation to a problem, in order to find a solution, or a hypothesis, which is sought to be confirmed, or with the aim of discovering new events or relationships between them.

To collect the data, a semi-structured interview was recorded with chemistry teachers who teach classes to visually impaired students in the second grade of high school in the city of Arapiraca, in two state high school education units: Arthur Ramos State School of Basic Education and Professor Moacir Teófilo State School of Basic Education. It was possible to carry out the interviews with the teachers because these selected institutions have teachers who have experience with visually impaired students.

The interview is characterized as a meeting between two individuals, with the purpose of one of them obtaining information on a particular subject, through communication of a professional nature. It is a strategy used in social investigation, to gather facts or to assist in the diagnosis or treatment of a social problem (Marconi and Lakatos, 2017).

To ensure the ethical integrity of the research, all participants were approached in a transparent manner, providing detailed information about the objectives of the study, the procedures involved and any possible risks or benefits associated with their participation. Before starting data collection, participants were asked to provide written

informed consent, indicating their understanding and voluntary agreement to their participation. Furthermore, the anonymity of the participants was ensured, using identification codes or numbers instead of personal information, and all responses were treated with total confidentiality, being accessible only to the authorized research team.

6.1 Analysis Type

The analysis used in this research is qualitative in nature, given that the information obtained is not quantifiable and is characterized by an interpretation of the phenomenon studied. Thus, qualitative research is essentially interpretative, since the researcher interprets the data. The observer develops a description of the environment or person, analyzes the information to identify themes or categories, with the aim of explaining the phenomena and assigning meanings (Creswell, 2010).

6.2 Data analysis

The information obtained through this study was analyzed based on Bardin's (2016) content analysis proposal, which aims to understand and interpret the information and characteristics present in the excerpts from the teachers' speeches.

Based on this point of view, content analysis is defined as a "set of techniques for investigating communications, which aims to obtain systematic and objective procedures for describing the content of messages" (Bardin, 2016, p.37). In his study, Bardin points out that the use of content analysis involves three fundamental phases.

The first phase of data analysis, known as pre-analysis, is important for organizing initial ideas and establishing the indicators that will guide the analysis of the information collected. This phase involves carefully reading the material collected, which, in the case of interviews, needs to be duly transcribed. It is important to systematize the material to be analysed in order to facilitate the successive exploration procedures and allow for a more in-depth and accurate analysis of the data.

The second phase, called material exploration, comprises the procedures for coding and categorizing the material collected. In this phase, counting rules are carried out, texts are cut into units of meaning and information is associated into categories and/or subcategories. The content of the interviews and other materials is separated into units of meaning, so that patterns and trends relevant to the study can be explored

and identified.

The third phase, called processing the results, consists of understanding the content present in all the material collected through interviews, documents and observations. The comparative evaluation is carried out by juxtaposing the numerous categories present in each analysis, highlighting the aspects considered identical and those understood to be distinct. In short, the interpretation phase seeks to infer and interpret the results obtained in order to reach conclusions about the phenomenon studied.

7 Results and Discussions

This section presents the paths taken to carry out the study, as well as the results obtained during the semi-structured recorded interviews with the chemistry teachers. In order to identify the teachers taking part in the study, we used the symbology: PQ1, PQ2, PQ3 and PQ4, based on the order in which the interviews were carried out, always adding the word "teacher" to the male gender, in order to protect the identity of the interviewees, but emphasizing that there are male and female teachers taking part in this investigation.

The interviews were audio-recorded and the information from the participants was transcribed and analyzed qualitatively, based on the content analysis proposed by Bardin (2016). The first phase, pre-analysis, comprised several essential stages for defining the categories and developing this study. Initially, the documents were read, allowing the researcher to immerse themselves in the content in order to identify trends, themes and relevant issues.

The documents that made up the research corpus were then chosen, taking into account their suitability for the study's objective and the representativeness of the topic. During this phase, hypotheses were formulated, providing a theoretical framework for the analysis. Index referencing and the development of indicators were also carried out to guide coding and subsequent analysis. In the material exploration stage, the researcher examines the content of the documents in detail, identifying relevant units of meaning and grouping them into categories.

The treatment of the results obtained, through inference and interpretation of the results, made it possible to relate the categories identified to the research objectives and the theoretical context. These stages were fundamental to guaranteeing

the validity and reliability of the content analysis, providing an in-depth understanding of the material investigated.

7.1 Teachers' training processes and experiences

The results presented below are related to the answers given by the chemistry teachers in the semi-structured interview about their training processes and teaching experiences. Initially, the following questions were asked: What is your educational background? How long have you been a teacher? Have you taken or are you taking any continuing education courses? Which one or ones?

Chart 1: Categorizations relating to teaching qualifications and professional experience

CATEGORIES	DESCRIPTIONS	UNITS OF MEANING
TEACHING QUALIFICATIONS	Initial teacher training	**PQ1:** I recently graduated from the Federal University of Alagoas with a degree in Chemistry. **PQ2:** I graduated from the State University of Alagoas. I started my studies in ninety-eight and finished them in two thousand and six, I have a degree in Chemistry. **PQ3:** My degree is in Chemistry. I graduated from the State University of Alagoas (UNEAL), Arapiraca campus. **PQ4:** My degree is in Chemistry.
	Continuing training for teachers	**PQ1:** Not at the moment. **PQ2:** I'm not doing it now, but there was a specialization course a while ago, offered by UNEAL itself. Our universities, here in the city of Arapiraca, don't offer postgraduate courses, it's very limited. I'm also quite busy, so it's difficult to take part. **PQ3:** I'm enrolled in a specialization selection process. **PQ4:** I did my master's degree in Chemistry and Biotechnology at UFAL's Chemistry postgraduate program and I'm currently doing my doctorate in Biotechnology at RENORBIO.
PROFESSIONAL EXPERIENCE	Time working	**PQ1:** I've been teaching for four years. **PQ2:** I have over thirty years' experience in the field. **PQ3:** I've only been a teacher for a very short time, since April of this year. **PQ4:** I graduated in 2020, about two and a half years ago.

Source: Authors

From the answers obtained in the semi-structured recorded interview, we found that all the chemistry teachers are civil servants in the Alagoas state education system and have a degree in chemistry from higher education institutions located in Maceió or

Arapiraca. Chart 1 shows that only teacher PQ2 completed a specialization course at the State University of Alagoas (UNEAL).

When we look at the "teaching qualifications" category, we see that only teacher PQ4 has a master's degree from the Chemistry Postgraduate Program at the Federal University of Alagoas (UFAL), and is currently studying for a doctorate in Biotechnology through the Northeast Biotechnology Network Program (RENORBIO). As for the "professional experience" category, most of the teachers have little experience in the area, except for teacher PQ2, who has worked as a chemistry teacher for over thirty years.

The process of training teachers, like other issues in the field of education, is understood from a number of perspectives. In this context, Garcia (1999) points out:

> Teacher Training is an area of knowledge, research and theoretical and practical proposals which, within the framework of Didactics and School Organization, studies the processes through which teachers - in training or in practice - engage individually or as a team in learning experiences through which they acquire or improve their knowledge, skills and dispositions, and which enable them to intervene professionally in the development of their teaching, the curriculum and the school, with the aim of improving the quality of the education that students receive (p. 26).

García (1999, p. 179) also points out that "[...] one of the advantages that teachers gain from taking part in a training course is the improvement of their teaching skills, which will allow them to develop their own training path". Thus, the author shows that a training course should be understood as a starting point which, throughout the teacher's professional qualification process, will be complemented by other training modalities.

Nóvoa (1997) advocates that teacher training not only takes place through personal development and professional development, but also by changing the school culture, which involves building, implementing and strengthening new educational practices. Nóvoa (1997) also points out that:

> Teacher training must be conceived as one of the components of change, in close connection with other sectors and areas of intervention, and not as a kind of precondition for change. Training is not done before change, it is done during it, it is produced in this effort to innovate and find the best ways to transform the school (p. 28).

In light of the above, it is essential that degree courses rethink their teacher

training practices, so that they are not restricted to techniques and methods, but also include theories and practices that promote professional development and autonomy. With more effective teacher preparation, it is possible to strengthen and foster the quality of student care, as well as enabling the development of new skills and competencies, which is essential for the continuous improvement of education.

In order to gain a deeper understanding of the teachers' professional training and their experiences in teaching visually impaired students, the following questions were asked: How do you assess the training of chemistry teachers to work in inclusive classes? Do you teach students with visual impairments? If so, for how long? The results are shown below:

Chart 2: Categorizations on vocational training and teaching visually impaired students

CATEGORIES	DESCRIPTIONS	UNITS OF MEANING
PROFESSIONAL TRAINING FOR TEACHING STUDENTS WITH DISABILITIES	Poor teaching qualifications and training only for deaf students.	**PQ1:** Training doesn't prepare us to deal with these diversities. In this case, the course I took was Brazilian Sign Language (Libras). We saw this in the second term, so that we leave the degree only seeing Libras in the second term and only Libras. **PQ4:** I don't think they look for this inclusive part in their training. I myself only had Libras, but no other subjects for inclusive training.
	Lack of practical training for teachers in Inclusive Education	**PQ3:** Look, it's not enough, because, in fact, although we have some subjects that talk about it in our degree course, we don't have anything practical.
PROFESSIONAL EXPERIENCE WITH VISUALLY IMPAIRED STUDENTS	Teaching visually impaired students	**PQ1:** Only one student at the moment, he only has a visual impairment in one eye. For two months now. **PQ2:** Look, I've had the opportunity to teach both deaf-mutes and those who are blind or visually impaired. I taught second and third grade. I taught for two years. **PQ3:** Yes, I've been teaching for about three months. **PQ4:** Yes, about three months.

Source: Authors

From the information presented in the category "professional training for teaching students with disabilities", as shown in chart 2, it is possible to see that the teachers investigated had insufficient initial training in relation to teaching students with disabilities. Teachers PQ1 and PQ2 emphasize that their training did not prepare them to deal with diversity. In this context, França (2018) states that the subjects related to school inclusion that are offered in Chemistry degree courses are generally non-compulsory, which results in teachers not being trained for inclusive teaching in mainstream schools.

Teacher PQ2 highlighted the lack of practical preparation during teacher training for inclusive teaching. According to Paula's (2015) observations, there is a need for practical training, as most of the time, teachers' training is out of touch with the reality in the classroom. As for the category "professional experience with visually impaired students", teachers PQ1, PQ2 and PQ4 said they had little experience teaching these students, although PQ2 had taught a student for approximately two years.

When it comes to teachers teaching students with disabilities, we can see that there are numerous shortcomings to be filled during training courses, since teachers often consider themselves incapable of teaching students with disabilities. According to Beyer (2003, p.1): "they lack understanding of the proposal, corresponding conceptual training, mastery from the point of view of didactics and methodologies". In view of the above, there is a clear need for these professionals to be better prepared and qualified to teach in the face of the diversity found in educational institutions.

By receiving adequate training, teachers are able to develop skills and competencies to meet the diverse learning needs of students, enabling them to participate fully in the educational process and reach their full academic potential. In order to understand more about the initial and continuing training of teachers from an inclusive perspective, the following questions were asked: How was your training in relation to teaching visually impaired students? Do you consider it sufficient for your work in the classroom? Have you taken part in any continuing training courses for teaching visually impaired students? Why? The teachers gave the following answers:

Chart 3: Categorizations related to the initial and ongoing training of chemistry teachers from an inclusive perspective

CATEGORIES	DESCRIPTIONS	UNITS OF MEANING
LACK OF TRAINING IN INCLUSIVE EDUCATION DURING THE UNDERGRADUATE COURSE	Lack of initial teacher training for teaching visually impaired students in degree courses	**PQ1:** I haven't had any related to this issue. No, I consider my training to be insufficient. **PQ3:** It fell short, just like all the other special needs. There's nothing we can do, for example, to deal with a student like that in a regular classroom. I don't consider it necessary to seek outside training. **PQ4:** I haven't had any subjects related to visual impairment. No, my training is insufficient for inclusive education.
LACK OF SPECIALIZATION IN THE AREA	Non-existent teacher training	**PQ1:** I haven't participated in training with visually impaired students. **PQ2:** No. **PQ3:** I've never taken part. **PQ4:** No.

Source: Authors

Chart 3 shows that in the category "lack of training in inclusive education during the degree course", teachers PQ1, PQ3 and PQ4 stated that they had not received any training in teaching visually impaired students during their initial training. As for the category "lack of specialization in the area", all the teachers who responded said they had not taken part in any continuing training course for teaching visually impaired students.

In this segment, studies such as those by Regiani and Mól (2013) and Mariano and Regiani (2015) emphasize that the initial training of chemistry teachers does not value diversity in schools. The authors also point out the importance and need for chemistry degree courses to include subjects in their matrices, curricula and course projects that encourage the training of teachers for diversity.

Still on the subject of training, chart 3 shows that teachers consider their work in the classroom to be insufficient for inclusive teaching. In this sense, Gonçalves et al. (2013, p. 265) argue that teachers who don't receive training that takes into account teaching in the midst of diversity are "unable to structure their pedagogical practice in such a way as to cater for the different forms of learning present in the classroom", given that, from the moment they are promoted, they are encouraged to invest in inclusive teaching, is encouraged and invested in preparation that provides opportunities and promotes inclusive educational practices, teachers will be able to "adopt inclusive educational practices when they are trained to do so, using pedagogical resources appropriate to each individual need" (Gonçalves et al. , 2013, p. 265).

In this scenario, initial and continuing teacher training is essential if the process of inclusion is to take place effectively in mainstream education, favoring the permanence of students with disabilities in schools. Another point to emphasize is the importance of including subjects that enable the construction or adaptation of teaching materials, the production of methodological practices for students with disabilities in training courses and experience in inclusive classrooms.

7.2 Teachers' difficulties in teaching thermochemistry from an inclusive perspective

The aim was to discuss the difficulties faced by chemistry teachers in teaching thermochemistry to visually impaired students. To this end, the following questions

were asked: Do you use any teaching methods or strategies to teach chemistry to visually impaired students? Why? When teaching thermochemistry, have you used and/or built any teaching resources adapted for the visually impaired? If so, which ones? The answers to these questions are shown in the chart below:

Chart 4: Categorizations relating to the application of accessible tools for teaching visually impaired students

CATEGORIES	DESCRIPTIONS	UNITS OF MEANING
USING DIDACTIC STRATEGIES TO TEACH CHEMISTRY	Use of methods or strategies for teaching visually impaired students.	**PQ1:** In his case, as he doesn't complain, because he can see out of his other eye, I don't prepare anything more specific. **PQ2:** Look, the most we did at the state school was use a machine to produce Braille texts. So, I used to produce texts and lacked all the symbology, for example, I translated a chemical reaction into Braille. **PQ4:** No, I teach with the help of the classroom assistant.
ADAPTATION OR CONSTRUCTION OF MATERIALS FOR TEACHING THERMOCHEMISTRY	Failure to use accessible teaching resources to teach thermochemistry.	**PQ1:** No! **PQ3:** Not when teaching thermochemistry. **PQ4:** I've never done it, no!
	Use of braille machines.	**PQ2:** No! As I told you, the only approach I had was to translate texts into Braille and as thermochemistry refers to chemical reactions associated with the release or absorption of heat. In this context, it was difficult to show my students. So it's equally difficult. We also worked a lot on the explanation aspect, which we would say was descriptive teaching rather than quantitative or analytical. It was simply descriptive, we talked about phenomena, we talked about heat, we talked about molecular agitation.

Source: Authors

Chart 4 shows that teachers PQ1 and PQ4 do not use any teaching methods or strategies for teaching visually impaired students in chemistry. Furthermore, none of the teachers interviewed reported having built or adapted inclusive teaching resources for teaching thermochemistry.

According to Duarte and Rossi (2021), the development and use of strategies, tools and didactic resources adapted for teaching visually impaired students are fundamental to providing these students with participation in the classroom context, promoting inclusion and autonomy. In addition, the authors point out that:

> [...] the limitation of specific teaching resources is a major barrier to assisting and supporting visually impaired students. It ends up falling to teachers to adopt or create strategies and teaching resources to develop their lessons, especially chemistry teachers (Duarte and Rossi, 2021).

In line with this, Mariano and Regiani (2015) argue that teachers who teach students with visual impairments need to be aware of these students' needs and prepared to look for new ways and means of planning, reviewing the way they teach and producing teaching methods and strategies that involve these students. However, in order for the teaching and learning process to achieve satisfactory results, it is necessary to make an effort on the part of various players, in addition to teachers, such as parents and the professionals involved.

We can see in chart 4 that only teacher PQ2 sought a strategy to promote the more effective participation of visually impaired students in the classroom, through the use of a machine to produce texts in Braille.From this angle, as highlighted by Brasil (2017), Braille transcription aims to enable the writing and reading of common textual content for blind students who know this system, which is crucial for the inclusion and development of these students.

Therefore, in order to meet the specific needs of chemical language, the Ministry of Education (MEC) developed Braille Chemistry for use in Brazil. This spelling makes it possible to represent formulas, symbols, substances, reactions and molecular structures, thus enabling visually impaired students to have access to the representational level of chemistry (Brasil, 2017).

In order to understand the challenges and difficulties faced by chemistry teachers when teaching thermochemistry to visually impaired students, the following question was asked: What are the biggest challenges and difficulties encountered when teaching thermochemistry to visually impaired students? The results are shown in the chart below:

Chart 5: Categorization of the challenges of teaching thermochemistry to the visually impaired

CATEGORIES	DESCRIPTIONS	UNITS OF MEANING
THE CHALLENGES OF TEACHING THERMOCHEMISTRY	No method or methodology to aid understanding	**PQ1:** The challenge would be the method or methodology so that they can have this understanding of graphs and everything else, because just explaining wouldn't help with this understanding, without visualizing the graphs.
	Difficulties transcribing braille for activities	**PQ2:** That's a big challenge! Presenting, translating and using Braille to make diagrams, for example, are fundamental for studying thermochemistry. Diagrams of chemical reactions and associations involving exothermic and endothermic processes for visually impaired students to understand.
	Content with visual representations	**PQ3:** The challenge is because it's very visual content. We use a lot of the visual side of chemistry.

		So it's a challenge to explain a graph, to explain the energy of reactants and products to this student. **PQ4:** It's very difficult for us to explain and for them to be able to learn, especially this part about graphs and equations.

Source: Authors

When we look at chart 5 on the challenges of teaching thermochemistry to visually impaired students, we can see that the teachers address different issues related to this topic. Teacher PQ1 highlights the lack of methods or methodologies to help teach and understand these students. In this logic, Salvador et al. (2018) emphasize that chemistry teaching is an area of visual representations, due to the fact that most of its content is related to micro and macroscopic levels. This makes it necessary to use methods and/or methodologies that help visually impaired students to understand this subject.

The authors also point out that the application of methodologies that enable students with disabilities to learn is beneficial for teachers, because degree courses do not prepare future teachers for a diverse job market. As a result, they train professionals who do not feel able to develop accessible materials and methods for teaching visually impaired students.

In this context, Nascimento (2020) points out that it is important that chemistry teaching for visually impaired students is carried out using methods, materials and methodologies that eliminate the barriers faced by these students, providing learning conditions similar to those of a normal-sighted student.

Teacher PQ2 points to the difficulty of transcribing into Braille as one of the challenges faced when teaching thermochemistry to visually impaired students. This difficulty is due to the need to represent graphs and equations, which makes writing in Braille more complex. In this circumstance, we highlight the use of Braille for teaching chemistry which, according to Duarte and Rossi (2021, p. 33):

> This is a very important tool for people with visual impairments to learn chemistry and follow the evolution of science, as well as helping teachers and/or professionals in this process. It provides representations of equations, molecular structures, symbols and formulas that allow visually impaired people, who use Braille as a means of reading and writing, to access this information.

Teachers PQ3 and PQ4 emphasize that teaching thermochemistry involves a lot of visual representations, which can be an obstacle for visually impaired students.

In this respect, Albano and Nogueira (2010) stress the importance of adapting chemistry teaching for these students, due to the frequent use of graphs, tables, symbols, equations, shapes and diagrams. It is important to note that many text reading programs are unable to adequately describe some content, such as that related to organic, inorganic and physical chemistry.

8 Final considerations

School inclusion is characterized as a process of valuing diversity and interpersonal relationships. Therefore, it is essential to emphasize that it is not enough to integrate, since integration alone does not transform. It is necessary to include students with visual impairments in an unrestricted and continuous way, since inclusion takes place together with the school, the other students and, above all, the teacher.

The answers obtained in the interviews showed numerous difficulties in teaching thermochemistry to visually impaired students from an inclusive perspective. Among these obstacles, the teachers mentioned the lack of practical and often non-existent training during their undergraduate studies and the challenge of using Braille writing and building and/or adapting accessible and tactile teaching resources to teach this content.

The results of this study lead us to conclude that the chemistry teachers taking part in this study do not feel prepared to work with visually impaired students, as none of the teachers had subjects during their undergraduate studies that worked from an inclusive perspective. In this way, we realize that changes in training practices in undergraduate chemistry courses are necessary and indispensable, since most of the time, teacher training is far removed from the reality in the classroom.

Finally, we hope that this study will spark reflections and incentives for new work and research that promotes the process of including visually impaired students in the teaching of thermochemistry and assists in the development of assistive technologies to collaborate and favor the teaching-learning process of students.

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