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# DIDACTIC-PEDAGOGICAL STRATEGIES SUPPORTED BY MAKER EDUCATION FOR THE TEACHING-LEARNING OF MORPHOLOGICAL DIFFERENCES OF VERTEBRATE ANIMALS OF VISUALLY IMPAIRED STUDENTS

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**SUMMARY**
Maker education is aligned with active methodologies in terms of bringing plurality of strategies that involve students in teaching-learning, interactively and innovatively. This study is based on this theoretical perspective, inserting it in the aspect of inclusion, involving students with visual impairment (VD) in the municipality of Rio Verde – Goiás, who attend elementary school I. The objective was to develop pedagogical materials produced in the 3D printer for students with visual impairment and evaluate them in classroom situations. In the methodology, initially, a diagnosis was made about the teaching-learning process of students with VI, through the observation of the school environment and with two teachers through dialogue to understand the context of the methodologies that are proposed for students with VI. After the diagnosis, 3D printed materials of vertebrate animals were produced, to exemplify how the body segments are in vertebrate classes, then some classes were developed with students with VI using these materials, and the results were analyzed through evaluative actions.

**Keywords:** Maker Education. Inclusion. 3D printing.

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## INTRODUCTION

Currently, there has been a debate about the difficulties encountered in the school to propose activities that are effective and playful, about working with visually impaired students (Primo; Pertile, 2022). Despite the technological leap in all social spheres in recent decades, methodological advances, the proposition of new educational theories in the academic environment and the support of the National Common Curricular Base (BNCC) — which, although limited by prioritizing technical skills to the detriment of a more critical and civic education — there is still a problem in basic education schools regarding the implementation of integrative and/or active methodologies. One of the aspects of this problem stems from the training and lack of diversity of didactic-pedagogical materials that are offered to teachers, so that they can dynamize their classes and permeate knowledge, using innovative methodologies (Costa; Santos 2021).

According to UNIFESP (Federal University of São Paulo) (2020), Visual Impairment (VI) occurs when there is partial or total loss of the ability to see, either in one or both eyes, being categorized as total blindness or low vision. According to the International Statistical Classification of Diseases and Related Health Problems (ICD) of the World Health Organization (WHO), blindness is diagnosed when the visual capacity is less than 0.05 or the visual field is less than 10º. Low vision, or low vision, is diagnosed when the corrected visual capacity in the better eye is less than 0.3, but greater than or equal to 0.05, or when the visual field is less than 20º in the better eye, even with the best optical correction. (Unifesp, 2020).

According to Primo and Pertile (2022), the needs arising from low vision are very variable and educational aspects are established based on the evaluation of vision functionality. In general, people with low vision have reduced vision and need the help of optical resources, magnifying glasses and lenses, and/or non-optical resources, such as accessibility *software* and expanded materials, making it necessary, in some cases, to use three-dimensional models, models and geometric shapes.

Considering the previous statement and being aware of the main methodological tools in Brazilian public schools, which are the blackboard, the slide projector and textbooks for visually impaired people (people without visual impairment). Although they are versatile tools and are capable of streamlining teaching-learning, it is impossible for students with VI to fully benefit from this methodology, which directly contradicts the Brazilian Inclusion Law (Brasil, 2015), which guarantees "it is the duty of the State, the

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family, the school community and society to ensure quality education for people with disabilities, safeguarding her from all forms of violence, negligence and discrimination" (Brasil, 2015, p. 07). However, as brought by Costa and Santos (2021), as much as laws play a crucial role in the process of inclusion in an educational environment, by themselves, they do not guarantee significant changes in the development of inclusive methodologies.

This narrative is complemented by Miranda (2019), about the responsibility that the school has to provide a holistic, robust and articulated pedagogical portfolio that speaks to the weaknesses that are found in the classroom and proposes the use of support materials, in addition to the traditional ones, to disseminate the content more organically and practically. Such technologies have been increasingly incorporated into the school reality since 2011, encouraged by the MEC, contributing to the fact that education can be guaranteed from the perspective of the process of school inclusion and active participation of students in the construction of their knowledge (Pedrosa; Guimarães, 2016).

Given the above, this article has as its general objective to develop pedagogical materials produced in the 3D printer for students with visual impairment and to evaluate them in classroom situations, as a way to guide the implementation of tactile experimentation activities, using, for example, modeling clay as an understanding of the activities.

## THEORETICAL FOUNDATION - TEACHING-LEARNING AND INCLUSION

In the Theoretical Foundation, two important topics will be addressed for the understanding of inclusion, starting with the historical path of the process of inclusion in society and the phases of the social process until inclusion is accepted as a right and duty of the state and the school. In the second topic, the methodological reception offered by maker education and active methodologies that can enhance the teaching-learning process for students with disabilities will be addressed.

### PATH AND CHALLENGES TOWARDS SCHOOL INCLUSION IN BRAZIL

As pointed out by Montoan (2006), when talking about disability, especially in the school environment, there are intrinsically several factors that interact with each other for a context of inclusion to occur, however, there is a scenario of exclusion and segregation that develops and extends, since before the discussion on education and schooling, being, even today, underestimated in its importance and social impact. According to Sassaki (1997), the phases of development of this agenda are subtle in their differences and can last for decades, until they permeate different layers of society.

The first phase is based on the exclusion of people with disabilities, placing them on the margins of society and denying them the right to citizenship and fraternity, even attributing forces of the supernatural as a response to the individual's disability (Miranda, 2019; Mendes (2006).

The second phase observed is institutional segregation, in which there is knowledge of these people with disabilities, but who are not welcomed by government institutions that can provide medical, educational and social care. There is the emergence of voluntary institutions that will keep children under permanent care in some cases, but there is also the creation of specialized centers that offer professional training to those who are judged productive, (Capellini, 2005; Sassaki, 1997).

From the 80's on, Sassaki (1997) observes that society, for the most part, will adhere to the third phase in the process of educational development of inclusion, called integration, in which it is used to this day, in some places, based on the sharing of common places, such as schools, but imposing that the subject must adapt to the environment, overcoming its deficiencies and maintaining a uniform methodology aimed at students.

As a last phase, we have inclusion, which will appropriate pertinent speeches and concepts, such as the Salamanca Declaration, which aims to seek and guarantee rights for people with disabilities, understanding that it is necessary for a valid and full interaction between all parties of inclusion. It is necessary not only to be in the same space, but also a well-equipped and adapted structure, methodologies that speak to the weaknesses that will be found and especially laws that will ensure that all these components are guaranteed and functional (Sassaki, 1997; Mantoan, 1997).

As for the context of Inclusive Education in Brazil, it began in 1854 with the creation of two institutions, both in Rio de Janeiro, the Imperial Institute of Blind Boys, which is currently called the Benjamin Constant Institute, and the Institute of the Deaf and Dumb, 3 years after the first, which today is called the National Institute of Education of the Deaf. As presented, in the phases of development for inclusive education, centers were created for the teaching of students with disabilities, however not providing opportunities for their inclusion in regular classes, but creating a separate space, where they would belong to an integrated education system. This fact only reinforces the discourse that inclusion is not necessary, and that there is a division between students who have disabilities (PCDs) and students without disabilities (PSDs) (Processes of Constitution of the Subject in Educational Practices, 2021).

In 1973, the Ministry of Education (MEC) created the Educational Center for Special Education (CENESP), which would be responsible for the issue of special education in Brazil, but no laws had yet been provided that formalized the requirements for inclusion to be adhered to by the School and the State (Mec, 2008).

The 1988 constitution was essential for the inclusion process, dictating Article 208, guaranteeing as an obligation of the State, compulsory and free elementary education, specialized educational assistance to people with disabilities, preferably in the regular school system, and combating prejudice with Article 3, item IV, which aims to combat prejudice of origin, race, sex, color, age or any other form of discrimination. But it was only in 1999 that Law No. 7,853/89 was regulated, which defines special education as a transversal modality and emphasized the role of special education as a complement to regular education. In 2001, it was established that all students should be enrolled in educational institutions and that it would be up to the schools to receive them in a welcoming and undifferentiated way. It also recognizes people with disabilities, having the same human rights and fundamental freedoms as the others in the Guatemala Convention in 1999 by Decree 3.956/2001 (Mec, 2008).

In 2002, there was the approval of the use, in addition to teaching, and dissemination of the Braille System for the inclusion of people with visual impairment, being considered a milestone in inclusive education in Brazil, reinforcing the statement that the school must adapt to the students who will be received, providing an environment of interaction between students and teachers. In 2003, promoted by the Ministry of Education, teachers, managers and students, in general, were included in the Inclusive Education: Right to Diversity program, in which they were trained to promote access to schooling for students with disabilities (Mec, 2008).

## ACTIVE METHODOLOGIES AND MAKER EDUCATION AS DRIVERS OF INCLUSIVE TEACHING-LEARNING

Considering the previous topic about the obstacle faced by inclusive education, new theoretical approaches such as active methodologies can enhance the teaching-learning of students in a fluid way and based on their protagonism in the construction of their knowledge. Morais, Rosa, Fernandez, Senna (2017).

As elucidated by Moran (2015), standardized education considers that all students are equal and learn in the same way, disregarding individuality in the way learning occurs. When the school uses traditional and rigid methodologies, it will be common to obtain results from students that are only plastered in what was taught, as it is limited by teachers that students interact meaningfully with the object of study and research on their own, according to Morais, Rosa, Fernandez, Senna (2017). Bringing an additional limitation regarding students with disabilities, in particular students with VI, who need tools that will enable the understanding of the object of study in a tactile way.

According to Paniago (2024), the lack of new approaches that support current teaching-learning and highlight new concepts that endorse the issue of education is evident, such as active methodologies and Maker Education, which, although they are different fronts, aim at the active participation of the student, making him the builder of his knowledge. Paniago (2024) also emphasizes the methodological potential of Maker Education, which is important not only in student learning, but also in the construction of an investigative and reflective teacher who appropriates new forms of teaching to materialize an articulated teaching.

In parallel, presented as a pedagogical opportunity, maker education became globally popular in 2005 (Blikstein 2013) arrived in Brazil in the mid-2010s and, since then, has been gaining strength in educational institutions, both higher education and basic education, standing out for presenting plurality in its practice.

In this context of yearning for an active methodology that breaks the protocol of traditionalist education, as previously presented, and with the emergence of the maker culture, which calls the community to create and express itself through the development of projects, Papert (1985) will bring the opportunity to add this methodology to education, being called maker education, Maróstica (2023). Maker education does not aim at construction itself, but focuses on the interactions between individuals and their experiences. Maker education will be proposed by Papert, a South African mathematician and educator, who, using Piaget's constructivist theories, states that the growth of students is improved when it is based on their protagonism and the consolidation of knowledge through the construction of a work. According to Maróstica (2023, p.31),

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A maker scenario encourages protagonism, cooperation, responsibility, critical and creative thinking, in addition to encouraging students to develop hypotheses to solve problems and conflicts, collaboratively.

In addition, in a maker space, the student goes beyond the list of curricular content. By creating, building, rebuilding, students apply the concepts and also elaborate concepts that they have not yet learned, effectively uniting theory and practice.

One of the ways that maker education can manifest itself is through 3D printed didactic models, which address diverse content and elucidate, in a more active way, the topic being studied. Santos and André (2020) state that the massive popularization of 3D printers, especially in the educational environment, happened mainly due to the sharing of source codes in online repositories, which made them accessible to the general public. According to Blikstein (2013), the significant reduction in prices helped small groups to develop their models of 3D printers in a few days.

Recognized for its educational potential for placing the student at the center of the dynamics and creatively valuing their experiences, both maker education and maker culture induce the creation of spaces for the creation of projects called makerspaces or fab labs, Samagaia (2015), which have been increasingly fostered by public policies such as innovative education,  generating 100 new units in 2020, Ministry of Education (2020).

Santos (2022) states that methodologies that participate in the maker movement are extremely versatile when it comes to applications, as they arise from manual work, from narrated stories to robotics and prototyping, allowing users to play, manufacture, and interact with their product (Samagaia, 2015).

## METHODOLOGY

The present research is based on the definitions of Gil (2002), using exploratory field research, which, by its nature, goes beyond geographic data and can incorporate cultural information, social interaction or individual activities.  The author also points out that it can encompass the collection of information from third parties about the object(s) of study, even appropriating multimedia tools, such as photographs or videos that help to elucidate the theme. Gil (2002) also points out that the researcher must have a temporary immersion to understand the context of the environment, community or individual studied, and to enable a more complete data collection.

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This study was carried out with the contribution and support of the Federal Institute of Goiás, Rio Verde Campus, which proposed the place where the experimental class was held, in addition to offering transportation to students and guardians who participated in the project. The initiative was also supported by the Municipal Department of Education of Rio Verde, which made time available for alignment meetings and indicated the students and teachers who would be candidates for the research. The didactic models manufactured by 3D printing and the filament used were paid for by the researcher, however the digital models were obtained from an[9]open digital platform called Thingiverse. An equally important part of the project was the support of the Prototyping Laboratory Estação IF - Lab Maker of the Rio Verde Campus, which provided the space for the programming and realization of the activity, some equipment, such as printers and notebooks, in addition to training the student at the head of the project with the knowledge of modeling and 3D printing.

In the municipality of Rio Verde, Goiás, until the date of the research, there are three visually impaired students enrolled and assiduous in the school environment, who are in the 4th year of elementary school, however, after the presentation of the research proposal to the parents/guardians, only 2 students participated in the project, even so, totaling 67% of the visually impaired students attending elementary school in the municipality.

First, the logbook was used for data collection to record the questions and record the answers given by teachers and students. The observation of the students' school environment was made during the SEA (Specialized Special Service) classes, which are taught by a teacher in the area of inclusion, in which the student's needs are verified, and during the after-hours, she holds the reinforcement class.

Through observation and dialogue between the two teachers and with the VI students, the use of different didactic materials for the teaching of VI students was discussed. These questions aimed to clarify the dynamics in the classroom, not only in present methodologies, but in the issue of student participation and involvement, interaction in the classroom and with colleagues, in addition to the teacher-student relationship.

[9] Our thanks to the thingiverse platform for making the models of vertebrate animals available for the prototyping of this work, on behalf of the following profiles and users: 3D_FlexSeeds, DragonArtist, Gabriel's 3D Printing, Jipcutter, PauloAmaral, Raj72616a, Simonarri, Schlossbauer, William_Additive and YahooJAPAN.

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Based on the initial diagnosis, a development and expansion of the pedagogical materials of Elementary School I that addressed the content of vertebrate animals in the discipline of Natural Sciences was designed, and a class was conducted using these materials to collect data from the practice carried out, since it is a theme studied since elementary school,  in a basic way, even ecological relations in high school, according to the BNCC.

During the experimental classes, photographic and video records were made of the moment of exploration of the material by the students and the participatory result, in this case, the modeling that the students made from the modeling clay with similarity to the animals observed. After the didactic action carried out with the students, using the didactic materials produced in the 3D printer, the learning result was analyzed, to conclude whether the practice has the potential to be incorporated as an active methodology routinely.

**Figure 1:** Skills and competencies taken from the BNCC that explain the study of vertebrate animals in elementary school.

**(EF01CI02)** Localizar e nomear partes do corpo humano, representá-las por meio de desenhos e explicar oralmente suas funções.

**(EF02CI04)** Descrever características de plantas e animais (tamanho, forma, cor, fase da vida, local onde se desenvolvem etc.) relacionados à sua vida cotidiana.

**(EF03CI04)** Identificar características sobre o modo de vida (o que comem, como se reproduzem, como se deslocam etc.) dos animais mais comuns no ambiente próximo.

**(EF03CI05)** Descrever e comunicar as alterações desde o nascimento que ocorrem em animais de diferentes meios terrestres ou aquáticos, inclusive o homem.

**(EF03CI06)** Comparar alguns animais e organizar grupos com base em características externas comuns (presença de penas, pelos, escamas, bico, garras, antenas, patas etc.).

**(EF04CI04)** Analisar e construir cadeias alimentares simples, reconhecendo a posição ocupada pelos seres vivos nessas cadeias e o papel do Sol como fonte primária de energia na produção de alimentos.

**(EF04CI05)** Descrever e destacar semelhanças e diferenças entre o ciclo da matéria e o fluxo de energia entre os componentes vivos e não vivos de um ecossistema.

**Source:** https://www.gov.br/mec/ptbr/escolaemempointegral/BNCC_EI_EF_110518_versaofinal.pdf

## REFLECTION ON THE DEVELOPMENTS OF THE RESEARCH

This chapter aims to expose the results of the data obtained in the first phase of the research, with students with VI and the regent and support teachers, as well as the observations of the school environment, and other reports that were told during the research, proposing a reflection in the light of researchers who develop work in the area of inclusion and active methodologies.

DIAGNOSIS RESULT

Examining the questions, it is possible to observe that there are, in fact, pedagogical tools that are used to complement the teaching of VI students in some disciplines. No complaints were presented from students 01 and 02 regarding being placed in any type of situation of exclusion or segregation by colleagues or teachers directly. However, the literacy situation of student 02 having started two years late demonstrates negligence on the part of the school, for allowing the student to follow the school routine without the accompaniment of a support teacher who had an understanding of braille.

Regarding the didactic materials aimed at the teaching of natural sciences that exemplify what animals of different classes are like, no materials compatible with the proposal were found in any of the schools. However, the existence and use of a typewriter adapted to Braille, the use of audios and interactive dynamics carried out by teachers in class, expose that both schools use it in different ways to illustrate the content in different ways to become accessible to students.

In the observation of the schools, it was noted that they are adapted for people with disabilities, there are adherence strips, handrails and ramps throughout the perimeter. Thus, SEA classes take place in a separate room, equipped with toys, decorated and air-conditioned, in addition to being well lit and having a range of equipment, such as screens, radios and the Perkins typewriter. However, during the reinforcement class, the student practices only writing and reading on the typewriter, not delving into other areas of knowledge. During the observation, the questions took place in the form of conversation, to make the answers more fluid and not to exert pressure.

Student 02, the first to be interviewed, was a little shy at first, but over time he developed his speech and talked more about his daily life and about other activities he develops outside school, such as athletics, with other students with VI, riding a bicycle in the area at home and playing with cars with his siblings. In addition to answering the questions, the student also inquired about the research that is being done, and was curious about the materials that would be manufactured and about the place where the experimental class would take place. After answering, the student finished his lesson using the Perkins typewriter, reciting the sentences he wrote at the beginning of the class with the help of the teacher.

The current teacher of the Specialized Educational Service (AEE) reported that, among the visually impaired students she accompanies, student 02 was the most impacted by the lack of school support. Until the 3rd grade, he had not been literate nor had knowledge of the letters of the traditional alphabet or in Braille, since his previous teacher was not proficient in this tactile writing system. This gap significantly compromised their academic development and their autonomy in learning.

It was only about a year ago, with the arrival of the current teacher at SES, that her literacy began to be worked on in a more in-depth way. Since then, the student has made remarkable progress, improving his writing to the point of being able to formulate complete sentences. This progress has not only broadened his academic skills but also strengthened his self-confidence and enjoyment of learning. According to the student himself, writing has become one of his favorite activities in the classroom, evidencing the positive impact of accessible teaching that is appropriate to his needs.

The observation of student 01 also occurred during classes in the SEA, but in the morning shift. Student 01 was more serious, also not showing discomfort during the conversation and the questions in the questionnaire. Student 01 did not encounter problems with literacy at the beginning of his school career, although he did not start in braille since preschool, the teacher made cutouts and collages of letters in high relief in his old notebook, explaining about each letter and familiarizing him with the alphabet. The student also talked about his favorite activities, he likes to run in the athletics that he participates in with student 02, and he likes to go to the farm with his parents. Because he has known the letters for a longer time, student 01 is already able to read and write a greater variety of words, he reported that he feels satisfaction in reading and writing.

Both students received, from the City of Rio Verde, glasses for each one, which is specialized for the visually impaired called OrCam MyEye, which performs basic functions of environment recognition, reads books, cell phones and other surfaces, in addition to recognizing more than 100 different faces, banknotes, products, colors, vehicles and reading aloud in the student's ear. These glasses cost around 15 to 16 thousand reais, and, according to students and teachers, it is an excellent tool on a daily basis.

In general, the data collected in the first stage of the research present a detailed analysis of the accessibility and pedagogical support offered to students with visual impairment (VI) in schools in Rio Verde, evidencing advances and challenges in the process of educational inclusion. It is clear that, although schools have good inclusion practices and assistive technologies, there are still structural challenges to be overcome, especially with regard to teacher training in braille and the adaptation of teaching materials for different subjects. The case of student 02 shows how the lack of adequate support can negatively impact learning, but it also demonstrates how the right pedagogical intervention can transform this reality. Thus, the narrative reinforces the continued need for investment in educational inclusion, ensuring that all students have equal opportunities for academic and personal development.

Another relevant point is the supply of OrCam MyEye glasses by the City of Rio Verde. This technology, evaluated as extremely useful by teachers and students, helps in reading, recognizing environments, products and even physiognomies, providing more independence in everyday life. Despite the existing resources, the data show weaknesses in the educational process, especially in the case of student 02. The absence of a teacher trained in Braille in the first school years resulted in a significant delay in their literacy, which constitutes a negligence of the institution in not ensuring adequate support from the beginning. This reinforces the importance of continuous training for teachers and public policies that ensure the presence of professionals specialized in braille from the first years of schooling of students with VI.

In addition, there is a gap in the teaching of natural sciences to blind students, since no adapted teaching materials were found that exemplified different classes of animals. This absence can compromise the understanding of fundamental biological concepts, demonstrating the need to invest in the production of accessible materials for disciplines that traditionally rely on visual representations.

And, finally, students 01 and 02 have different profiles in relation to learning and school development. Student 01, who had access to tactile methods to become familiar with letters from an early age, demonstrates greater fluency in reading and writing. Student 02, despite the initial difficulties, managed to develop a great appreciation for writing after receiving adequate support in the SEA, evidencing the positive impact of inclusive and specialized teaching.

## PRODUCTION OF TEACHING MATERIALS ON THE 3D PRINTER AND EVALUATION WITH STUDENTS WITH DV

After knowing the reality of the school and the teaching-learning situations of the two students, the process of producing teaching materials in the 3D printer for the teaching-learning of vertebrate animals began, and the first stage is the modeling in the 3D software, which gives the opportunity to focus on structures to be put in focus. There is now a range of free and easy-to-use software that is adopted for creating models, such as Tinkercad® and Blender®. (Silva, Vilas Boas, Belo Filho, 2023). An alternative is to download ready-made models for free from online libraries, which offer hundreds of STLs (format of a three-dimensional digital model) to address different subjects, disciplines and age groups.

Once the digital model is ready, it is necessary to export it to a second one, which will translate faces and vertices into print coordinates, called a slicer, such as the Creality Slicer®, which will slice the part into horizontal layers to be printed. At this stage, the print quality of the part, filling, which will impact the strength and weight of the part, and support configurations, which will support aerial parts, will also be configured. In addition, it is at this stage where the position, size and angle will be defined that the part will be printed. After this setup, the file is sent to the printer via Wi-Fi or using an external memory device (USB stick or memory card).

The mechanism of the 3D printer resembles a household hot glue gun. A material called filament is inserted, which is nothing more than a plastic material that will be pulled by the printer, and, when expelled by the nozzle heated from 185ºC to 260ºC, it becomes pasty. The nozzle will follow the coordinates of the file and draw on the print bed layer after layer, rising from the base to the top.

In addition to the power of adaptation that the printing methodology offers, it makes use of equipment that is increasingly being disseminated in public schools and a variety of topics studied in basic education can be addressed, from literacy to more specific topics such as cell biology, as has already been done in several schools throughout Brazil (Santos; Andrade, 2020). Projects, such as the creation of sketches, work with clay and dynamics with printed three-dimensional models, are more than a recreational activity, they are innovative pedagogical practices that offer an immersive alternative and integration of the content covered in the classroom (Silva, 2023).

After the production of the materials, the practices were carried out at the Prototyping Laboratory Estação IF - Lab Maker, located at the Federal Institute of Goiano, Rio Verde campus, at which time the students had the experience of handling and exploring the didactic materials, as well as getting to know the laboratory that is dedicated to maker culture and education, as well as the equipment and materials used for the manufacture of parts.

Despite being in a new and unknown environment, the students showed interest and curiosity in participating in the proposed dynamics. They had not had contact with 3D

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printers before, but they interacted with the material and made comparisons with other machines they already knew.

During the explanation, the way of life was explained and narrated how the main characteristics of the animals were presented, how they moved, and where they lived. There was also an analysis of a human torsion, where the disposition of internal organs, such as the heart, digestive system and lungs, was observed.

After the preparation of the dynamics and the realization of the didactic action, it was noted that the potential use of these materials is immensely dynamic and flexible, and can be adapted to a range of contents from different disciplines. The students felt comfortable manipulating the teaching materials, and, at all times, they made comparisons and associations, told their own experiences with other animals and how they felt about it.

Regarding the printed materials, it was found that there is a possibility of improvement in future productions, such as increasing the size so that specific structures and parts could be evidenced, also optimizing the size comparison between the animals. Another factor that can be improved is the articulation of the models. Most of the models were rigid, and did not elucidate how the movement of the animals occurred, such as displacement of the legs or wings, neck and trunk.

**Figure 2:** Analysis of the human torso and internal organs

**Source:** author, 2024.

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Student 02 had the opportunity to explore a tactile piece representing the human torso with removable internal organs. During the activity, the respiratory system and the digestive system were highlighted, allowing the student to identify, through touch, the location and structure of the main organs involved in each vital function. In addition, the general organization of the human body was addressed, promoting a deeper understanding of anatomy and inner workings. This sensory approach enabled a more accessible and meaningful learning experience, favoring the construction of knowledge in an inclusive and interactive way.

**Figure 3:** Poultry analysis – Flamingo

**Source:** author, 2024., 2024.

In the analysis of the 3D printed model of a flamingo, student 02 explored, through touch, the anatomical characteristics of the bird, with emphasis on its long legs and elongated neck. During the activity, it was possible to discuss the adaptation of these elements to the habitat and behavior of the flamingo, such as the importance of the legs for locomotion in flooded areas and the flexible neck for feeding. In addition, the tactile experience allowed the student to build a detailed mental image of the bird's body structure, enriching his understanding of the morphological diversity of species and their relationship with the environment. The interaction with the three-dimensional model favored inclusion, making the learning of students with VI more accessible and dynamic.

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**Figure 4:** Analysis of reptiles - snake

**Source:** author, 2024., 2024.

In the analysis of the 3D model of the snake, student 02 noticed the absence of legs and arms, comparing its elongated shape to a rope. From this observation, it was possible to discuss the evolutionary adaptations of this group of reptiles, such as wave-like locomotion, the importance of ventral scales for displacement, and the diversity of existing species. In addition, the activity provided a tactile understanding of the anatomy of snakes, allowing the student to build a more accurate mental image and reflect on the different forms of locomotion in the animal kingdom.  It was notorious how much this inclusive approach favored more concrete and accessible learning.

**Figure 5:** Analysis of birds – toucan

**Source:** author, 2024, 2024

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In the analysis of the image of the toucan, student 02 identified the bird perched on a tree branch and showed curiosity when asking about the animal. From this interest, its natural habitat was explained, highlighting the presence of the species in forests. In addition, their way of life was addressed, including their fruit-based diet, their role in seed dispersal, and their ability to fly short distances due to body structure. The interaction with the image and the oral explanation allowed the student to build a broader understanding of the ecology of the toucan.

**Figure 6:** Introducing the 3D printer and how it works.

**Source:** author, 2024., 2024.

In this figure, student 01 has his first contact with a 3D printer, while receiving explanations about its mechanism of operation. Showing curiosity, he questions whether the machine has gears and screws. In response, it is clarified that it does, in addition to containing belts and electrical wires, which play an essential role in the movement of components and the printing process. This interaction enables the student to have a more detailed understanding of the structure and functioning of technology, stimulating their interest in innovation and engineering.

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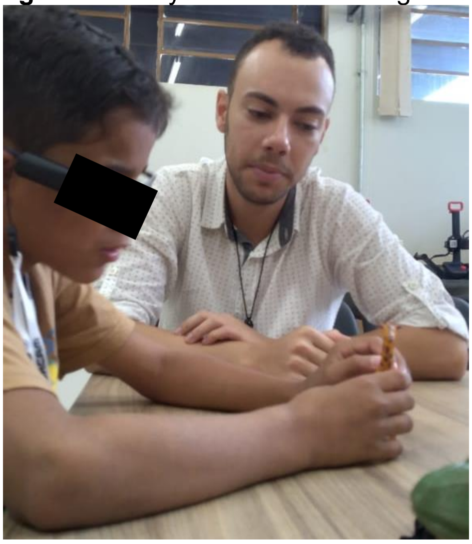
**Figure 7:** Analysis of mammals – giraffe.



**Source:** author, 2024., 2024.

During the analysis of the giraffe, one of the specimens of mammals, student 01 initially asks if the animal observed would be a horse. However, when he notices the elongated neck, he shows curiosity and asks what species it is. From this observation, the difference between the two animals is explained, highlighting the unique characteristics of the giraffe, such as its long neck, adapted to reach the treetops, and its long legs, which favor locomotion in savannahs. This interaction stimulates the perception and construction of knowledge about the diversity of mammals and their adaptations to the environment.

**Figure 8:** Analysis of laboratory materials.

**Source:** author, 2024., 2024.

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After the activity, student 02 was curious to know the other pieces that were in the laboratory, so he observed the available models.

**Figure 9:** Analysis of other laboratory materials.

**Source:** author, 2024., 2024.

Like student 02, student 01 also showed curiosity in exploring the various pieces available in the laboratory. During the interaction, he handled the materials, observed their characteristics and sought to understand their operating mechanisms. This active exploration allowed the student to make connections between theory and practice, deepening their learning about the concepts covered. In addition, direct contact with objects stimulated their autonomy and investigative sense, instigating curiosity to learn.

## LEARNING DIAGNOSIS ACTIVITY AFTER INTERACTIONS WITH THE DIDACTIC PIECES

After manipulating the printed materials, they were asked to reproduce, in the way they could, the exploited animals, using modeling clay. At first, they were insecure due to not using modeling clay in their daily lives and expressed that the result would not be similar. However, it was explained that it was not an evaluative activity, it was an experimentation, like a game, so each one developed some models of the animals that they felt would be more possible to reproduce.

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**Figure 10:** Reproduction of animals in modeling clay, student 01.

**Source:** author, 2024., 2024.

Student 01 started modeling an elephant on the first try. He showed that he was happy with the result.

**Figure 11:** Reproduction of animals in modeling clay student 01.

**Source:** author, 2024., 2024.

On the second attempt, he modeled a toucan on a tree branch, just like in the printed model.

The analysis of the learning process of student 01 in the modeling activity evidences his capacity for observation and tactile reproduction. The choice of the elephant as a first attempt may be in the face of an initial interest in larger shapes that are more easily perceptible to the touch. The fact that the student was satisfied with the result indicates a sense of achievement and motivation to continue exploring the technique. In the second attempt, the modeling of a toucan on a tree branch, based on the printed model, demonstrates an evolution in the creative process and a greater attention to structural details. This suggests that previous tactile experience contributed to the refinement of their spatial perception and three-dimensional representation. In addition, the activity reinforces

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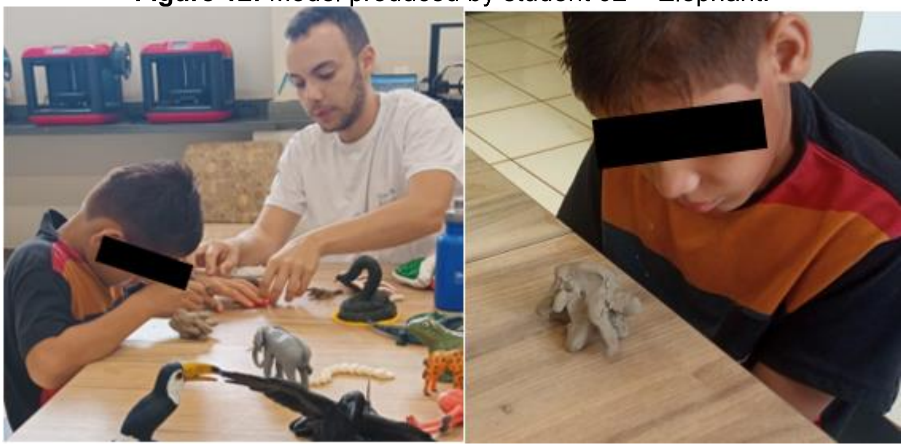
the importance of using accessible materials in the teaching of Natural Sciences, allowing visually impaired students to develop cognitive and motor skills through practical experimentation.

**Figure 12:** Model produced by student 02 – Elephant.



**Source:** author, 2024., 2024.

**Figure 13:** Models reproduced by student 02 – Giraffe on the left. Turtle and snake on the right.

**Source:** author, 2024., 2024.

Student 02 continued the modeling activity and reproduced three more animals after the elephant. During the process, he showed interest and got actively involved, exploring different shapes and textures with the playdough. According to him, the experience was fun, showing that the activity, in addition to stimulating creativity and motor coordination, provided a playful and pleasurable moment. This interaction reinforces the importance of the use of tactile materials in the learning of visually impaired students, allowing them to build more concrete mental representations of the elements studied. This is in line with what he proposes.

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Finally, based on Moran (2015), the data analysis highlights the importance of active and inclusive methodologies for the learning of visually impaired students, highlighting how experimentation and interaction with concrete materials favor the construction of knowledge. Modeling with playdough, for example, provided student 02 with a playful and meaningful experience, allowing him to explore shapes and textures autonomously. According to Moran (2015), learning becomes more effective when students are actively involved in the process, experimenting and attributing meaning to what they learn. In addition, the educational accessibility discussed throughout the text reinforces the need for personalized teaching, which includes different strategies and assistive technologies, such as the use of braille, tactile materials and digital resources. The delay in the literacy of student 02 evidences the lack of specific teacher training, demonstrating that inclusion goes beyond physical infrastructure – it requires pedagogical preparation to ensure equity in teaching. In this way, the analysis reinforces Moran's (2015) view of transformative education, which values students' autonomy and promotes dynamic, collaborative learning aligned with their individual needs.

## FINAL CONSIDERATIONS

This study aimed to develop pedagogical materials produced in a 3D printer for students with visual impairment and evaluate them in classroom situations. The analysis of the results showed that the use of three-dimensional models in the teaching of Natural Sciences contributes significantly to the understanding of the contents, enabling students with VI to interact in a more concrete way with the concepts addressed.

Although the materials developed were well received by the students, it was observed the need for improvements to provide even more tactile details, expanding the perception of the characteristics of the objects represented. The interaction with the pieces, combined with modeling with playdough, proved to be an important pedagogical strategy, stimulating creativity, sensory exploration and autonomy of the students.

In addition, it was found that playful and manipulative activities, such as educational games and assembly of plays, favor the active participation of students and make learning more dynamic and engaging. Thus, the findings of this study reinforce the potential of materials produced in 3D printers as inclusive resources, highlighting their feasibility in promoting a more accessible and equitable education for visually impaired students.

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