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Integration of educational robotics into the teaching of Mathematics: perspectives for promoting inclusion in southern Bahia

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Abstract: This article presents an excerpt of research related to the Research Group on Digital Technologies that Enhance Mathematics Teaching and Learning (GPTDEM). Specifically, this work is classified as exploratory qualitative research in which actions were documented in the development of prototypes for the Visual Aid Helmet (Capacete Auxiliar Visual - CAV), the Lubotica — Sensory Glove, and the game "Dê um up na inclusão" - Give a Boost to Inclusion, with students from a public school in Bahia. These actions made it possible to foster an inclusive mindset in students, as well as to bring dynamism to the classroom through games and programming. The results demonstrated that educational robotics integrated into the educational environment based on the guidelines set in the National Common Curricular Base (BNCC) linked to Mathematics contributes to the learning of People with Disabilities (PwD), and the development of students who are aware of inclusion.

Keywords: Educational Robotics. Mathematics Teaching and Learning. Scheduling. Inclusive Games. Inclusive Education.

Integración de la Robótica Educativa en la Enseñanza de Matemáticas: Perspectivas para Promover la Inclusión en el Sur de Bahía

Resumen: En este artículo se presenta un recorte de las investigaciones vinculadas al Grupo de Investigación en Tecnologías Digitales Potencializadoras de la Enseñanza y la Investigación en Matemáticas (GPTDEM). Específicamente, este trabajo se clasifica como una investigación cualitativa exploratoria en la que se evidencian las acciones en la construcción de prototipos como el Casco Auxiliar Visual (CAV), la Lubótica – Guante Sensorial, y el juego "Impulsa la Inclusión" con estudiantes de una escuela pública de Bahía. Estas acciones permitieron desarrollar en los estudiantes una conciencia inclusiva, así como dinamizar la clase mediante juegos y programación. Los resultados demostraron que la robótica educativa, integrada en el ambiente educativo según las proyecciones establecidas en la Base Nacional Común Curricular (BNCC) asociada con las Matemáticas, contribuye al aprendizaje de las Personas con Discapacidad (PcD) y a la formación de estudiantes con conciencia de inclusión.

Palabras clave: Robótica Educativa. Enseñanza y Aprendizaje de Matemáticas. Programación. Juegos Inclusivos. Educación Inclusiva.

Integração da robótica educacional no ensino de Matemática: perspectivas para promover inclusão no sul da Bahia

***Resumo**:* Neste artigo, é apresentado um recorte das pesquisas vinculadas ao Grupo de Pesquisa em Tecnologias Digitais Potencializadoras do Ensino e da Pesquisa em Matemática (GPTDEM). Especificamente este trabalho classifica-se como uma pesquisa qualitativa exploratória em que foram evidenciadas as ações na construção de protótipos do Capacete Auxiliar Visual (CAV); da Lubótica – Luva Sensorial; e do jogo "Dê um *up* na inclusão", com estudantes de uma escola pública da Bahia. Essas ações possibilitaram formar nos estudantes uma consciência inclusiva, bem como trazer o dinamismo para a sala de aula, por meio de jogos e programação. Os resultados demostraram que a robótica educacional inserida no ambiente educacional a partir das projeções postas na Base Nacional Comum Curricular (BNCC) atrelada à Matemática contribui para o aprendizado da Pessoa com Deficiência (PcD), e a formação de estudantes com consciência da inclusão.

Palavras-chave: Robótica Educacional. Ensino e Aprendizagem de Matemática. Programação. Jogos Inclusivos. Educação Inclusiva.

1 Introduction

In the last decade, changes in the curriculum due to technological advancements have taken into account pedagogical approaches in various contexts, considering social, cultural, and political elements. Curricular projects for Basic Education are being considered in the following aspects: What to teach? When to teach? How to teach? How to evaluate? (Coll, Schilling & Deheinzelin, 2003), contributing to the improvement of teaching and learning. With the advancement of Information and Communication Technologies (ICTs), pedagogical practices were redefined, and these issues began to be discussed by researchers, as highlighted by Bacich and Moran (2018); Valente, Almeida and Geraldini (2017); Moreira (2018); Nóvoa (2022); Moran (2018); Papert (1980); and Wing (2006).

According to Ponte (2004, p. 10), "the teaching of Mathematics was characterized by memorization and mechanization, also known as 'traditional teaching'; however, the results of this teaching methodology were not significant" (emphasis added). Currently, a teaching model and curricular innovation with interdisciplinary and inclusive pedagogical practices are being sought.

In this context, Gadotti (2000, p. 7) mentions that changes "are a space enhanced by new technologies, constantly innovating methodologies". For the author, innovation is related to novelty, although common sense suggests that the concept of innovation refers to what is unprecedented, "as if, in a flash of insight, we were able to create something entirely new, which does not incorporate anything from the old, or alternatively, the contribution of some aspect of tradition" (Gadotti, 2000, p. 7).

When proposing innovation, there seems to be an obligation to create, to be innovative. That is, innovation requires creativity, leaving the familiar behind and introducing new actions into what has become routine. Thus, the BNCC guides the preparation of curricula and new pedagogical practices with Active Methodologies (AMs), which make up the new educational scenario, so that the student is the protagonist of the process and the teacher is a knowledge mediator/tutor.

The BNCC outlines ten competencies that students must develop throughout the stages of Basic Education, as well as directs learning mediated by ICTs. It should be noted that the curricular base is not a curriculum, but a guiding document for states and municipalities, providing new guidelines and contributions, and considering social and regional aspects in education.

With the aim of standardizing the educational foundation in the country, the BNCC introduced the need for new teaching methods in the classroom. This impact is directly manifested in teachers' Initial and Continuing Education (ICE), as mentioned by Silva (2023). These professionals begin to design and conduct their practices beyond the limits of a specific discipline, as highlighted by the BNCC. The regulations highlight the importance of "commitment to students with disabilities, recognizing the need for inclusive pedagogical practices and curriculum differentiation, as established in the Brazilian Law on the Inclusion of Persons with Disabilities (Law 13,146/2015)" (Brazil, 2017, p. 16), and the need for teachers to adopt a more comprehensive approach.

The implementation of the BNCC's inclusive guidelines requires ICTs as instruments to transform pedagogical practice. The intersection of teacher education, BNCC, and ICTs represents a promising path to building an inclusive educational environment where each student has the opportunity to achieve their full potential.

The BNCC also addresses digital culture and reinforces this need in general competence 5 of

> understanding, using, and creating information and communication technologies in a critical, meaningful, reflective, and ethical way in various social practices (including school ones) to communicate, access and disseminate information, produce knowledge, solve problems, and exercise leadership and authorship in personal and collective life (Brazil, 2017, p. 9).

The promotion of digital culture not only facilitates the learning of mathematical concepts in dynamic, autonomous, and practical ways, but also helps create alternatives to promote digital inclusion and raise awareness about it in the educational process. From this perspective and with the aim of promoting digital inclusion and awareness of the inclusion of PWDs, this article presents an excerpt of research linked to the Research Group on Digital Technologies that Enhance Teaching and Research in Mathematics (GPTDEM) at the State University of Santa Cruz (UESC).

Thus, it is evident that educational robotics "serves as a means to facilitate scientific and technological knowledge, allowing students to directly engage with new technologies through practical applications related to subjects that are part of their daily lives" (Vargas et al., 2012, p. 4).

2 Computational Thinking and Constructionism

Despite its name, Computational Thinking (CT) is not a product of the information society, nor of computer science, although they are primarily responsible for its growing importance. According to Denning and Tedre (2019), CT appeared after mainframe computers.

Papert (1980), when defining constructionism, mentions the skills to be developed based on this educational paradigm, which is CT; however, he does so without elaborating further. Years later, Jeannette Wing initiated the discussion about what CT would entail, or thinking like a computer scientist, and what abilities that thinking encompasses (Wing, 2006).

The discussion about the nature of the CT, based on the development of a concept and a framework that encompassed its core competencies, was formally initiated in 2006. That year, Jeannette Wing argued that computational thinking would be increasingly necessary in a society with the growing use of computers. Especially at a time when education became accessible to all audiences, including students with disabilities, interacting in schools and communicating with students without disabilities.

Wing (2006) describes CT as a general-purpose tool, based on natural and artificial processes. They illustrate the CT's association with problem-solving, design, and the human condition itself and exemplifies this through processes such as compartmentalizing, abstracting, representing appropriately, reanalyzing, debugging, selecting, storing, etc.

Thinking about its inclusion in the teaching of Mathematics and providing teachers with references for pedagogical interventions and assessments, Weintrop et al., (2016) classified CT into four categories: practices related to data; modeling and simulation; computational problem-solving practices; and practices of systems thinking, which are divided into 22 other skills, offering one of the most extensive taxonomies of CT. This approach not only enriches your learning, but also provides a practical connection with mathematical concepts, promoting logical reasoning and contextualized problem solving.

According to research by Mohaghegh and McCauley (2016, p. 1526), CT is one of the ten competencies of future professionals in a globalized 21st-century world:

> 1. Sense-making, 2. Social intelligence, 3. Novel and adaptive thinking, 4. Cross-cultural competence, 5. Computational thinking, 6. New media literacy, 7. Transdisciplinarity, 8. Design mindset (represent and develop tasks), 9. Cognitive load management, 10. Virtual collaboration (collaboration in online environments).

Constructionism guides technology-based teaching (therefore, intrinsically associated with CT) and was developed by Seymour Papert and his colleagues at the Massachusetts Institute of Technology to enhance learning through the most advanced information technologies. Teaching practices that use programming to develop CT are at the heart of this paradigm, since they provide ways to formalize logical, mathematical, and abstract concepts, and allow learners to create tools.

2.1 Educational Robotics as a Tool for Developing Computational Thinking

The introduction of educational robotics, based on AMs integrated into the school curriculum, plays a central role in students' acquisition of multidisciplinary knowledge (H. Santos, 2023). By incorporating robotics in classrooms, students can explore various areas of knowledge, transcending the limits of a standardized and discipline-specific curriculum model. This dynamic approach enriches the educational experience and challenges the traditional separation between disciplines, creating an interdisciplinary environment that reflects the complexity of the real world.

Educational robotics goes beyond simply transmitting information to students, as it offers a practical and interactive approach, allowing them to develop skills applicable in different everyday situations. The interdisciplinarity thus promoted expands the scope of learning and prepares students to face complex challenges, encouraging a holistic and integrated view of knowledge (Fazenda, 2015).

Therefore, the inclusion of educational robotics in the context of AMs diversifies the educational experience and aligns the learning process with contemporary demands. By breaking down barriers between disciplines, robotics contributes to the development of students who are more adaptable, creative, and able to apply their knowledge in practical ways across various contexts (H. Santos, 2023). Understood as a distinct field of computing, programming and engineering are used to create autonomous machines, tools, and objects capable of performing tasks within the capabilities of their hardware with minimal human intervention.

Educational, or pedagogical, robotics derives from traditional robotics, which allows the replacement of human labor in repetitive or hazardous tasks. As stated by Santos (2023), in the educational context, it promotes multidisciplinary learning and interaction among students, stimulating creativity and cognitive development.

> Pedagogical robotics can be defined as the use of robotics in an educational context where the construction and control of devices, using assembly kits or other materials, facilitate the understanding of scientific concepts in a classroom environment, at various levels of education (D'Abreu, 1999, p.1).

Educational robotics "appears as a way to enable scientific and technological knowledge, allowing students to have direct contact with new technologies through practical applications related to subjects that are part of their daily lives" (Mahmud, 2017, p. 28). It has a constructivist nature, in which the student can analyze, question, construct, and test their ideas in order to acquire knowledge to solve a problem situation.

Playfulness, often associated with the design of robots, stimulates creativity and generates motivation. According to Vargas *et al.*, (2012, p. 6):

> The use of educational robotics as a tool for the teaching and learning process makes the academic environment more attractive and emphasizes its playful appeal, encouraging experimentation and stimulating creativity. It appears to be a way to facilitate scientific and technological learning, allowing students to have direct contact with new technologies and practical applications related to subjects that are part of their daily lives.

Educational robotics has the capacity to make programming playful (Santos, 2023), and to enable the exploration of knowledge and focus its pedagogical practice on actions where learned knowledge can be used as tools for construction.

Relevant to the use of educational robotics is the motivation factor:

> Motivation is recognized by many researchers as one of the greatest pedagogical benefits of Educational Robotics [...]. In fact (sic), Educational Robotics demonstrates great power to motivate and engage students in activities, stimulating their natural curiosity. In some studies, this enthusiasm led researchers to notice students who wanted to work during breaks, as well as typically inattentive students who showed unusual focus on new tasks. It is not surprising, then, that Educational Robotics is seen as a way to motivate students in more "challenging" areas, such as Science and Mathematics, where the need to attract students is recognized (Ribeiro; Coutinho & Costa, 2011, p. 441, original emphasis added).

Thus, when the autonomy of action provided by a constructionist approach is combined with the motivating elements, playfulness, and creative capacity of educational robotics, and the associated computer technology, it becomes possible to delve pedagogically deeper into mathematical complexity (F. Silva, 2019). It therefore contrasts with the straightforward resolution of isolated problems.

These changes in the educational system, such as demands for interdisciplinary practices, the teacher as a mediator in the process of constructing student knowledge, etc., as well as "studies with participatory and significant approaches are gaining strength and the post-pandemic period has revealed a lot about this issue, presenting discussions and scientific research" (J. Silva & F. Silva, 2023, p. 86), require teachers to rethink their teaching practices, many of them integrated with the ICTs that emerged to assist these professionals in the classroom (Valente, 2016).

The relationship between teachers and knowledge is no longer limited to the transmission of information. Teaching practice integrates different types of knowledge and involves diverse relationships with it. Above all, the multiple connections between teaching practice and knowledge make teachers a group that, in order to function effectively, must master, integrate and apply such knowledge in their practice (Tardif, 2002; 2014). This knowledge must be closely connected to the knowledge constructed by your students, especially regarding the teaching and learning of Mathematics through inclusive practices.

Educational robotics is often used as a strategy to develop computer skills in elementary and high school students. Empirical research shows that robotic activities implemented in formal education settings play an effective role in improving competencies related to computational technologies, such as sequencing, conditionals, loops, debugging, and algorithmic thinking (Kerimbayev *et al*., 2023).

The use of robotics kits, particularly Lego Mindstorms, has predominated in these studies (Ching & Hsu, 2023). Collaborative learning, project-based learning, and embedded learning are instructional strategies used in robotics activities. The research presented by Wang (2023) demonstrated that project-based, computer-supported learning can improve students' CT and engagement in robotics learning.

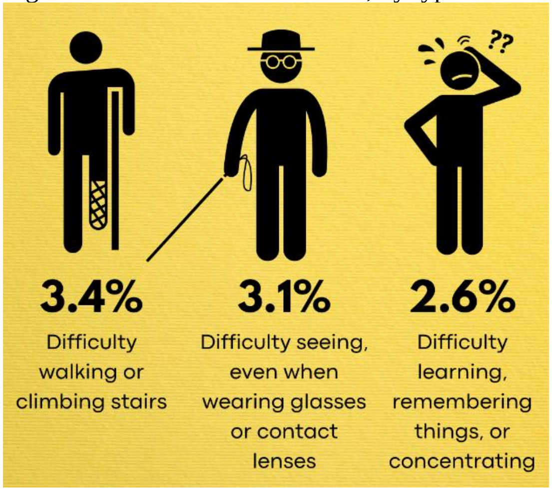
Learning and teaching using ICTs enhance algorithmic thinking, cooperation, and problem-solving skills through training in simulation projects (Bellas & Sousa, 2023). Educational robotics also offers a synergistic learning environment that encourages motivation, collaboration, self-efficacy, and creativity. Overall, it offers valuable opportunities for the development of CT competencies in students of all ages, from kindergarten to higher education (Munn, 2023).

2.2 Inclusion and Challenges in Mathematics Education

The CT and educational robotics have the potential to improve mathematics education and promote inclusive learning. Learning with projects that incorporate block-based programming environments, such as Scratch and Tinkercad, showed superior improvements in computer knowledge and 21st-century skills compared to other educational methodologies (Oliveira et al., 2022). Educational robotics is not only associated with disciplines such as Science, Technology, Engineering, and Mathematics (STEM), but it can also support and be integrated into inclusive education, meeting the diverse needs of students (Pou, Canaleta & Fonseca, 2022).

According to data from the Continuous National Household Sample Survey (PNAD) 2022, released in the People with Disabilities module, 18.6 million people, aged 2 years or older, had some type of disability in Brazil. The three main difficulties reported (Fig. 1) were: walking or climbing stairs; seeing; and lack of concentration or memory.

Figure 1: Percentage of people aged 2 and older with disabilities, by type of functional difficulty — Brazil, 2022



Source: IBGE (2022).

In the 2022 National Household Sample Survey analysis (PNAD) regarding PwD, the most common difficulty reported, at 3.4%, was related to walking or climbing stairs. Then, at 3.1%, is the difficulty in seeing, even when using glasses or contact lenses. Cognitive aspects are also mentioned, with 2.6% stating that they have difficulties learning, remembering, or concentrating. These data reveal that inclusive education is one of the current challenges for education in Brazil, especially regarding school structures that need to be accessible to all people, including students with specific needs.

These findings highlight the importance of integrating CT and educational robotics in the teaching of Mathematics to improve learning experiences and promote the inclusion of this audience, as they demonstrate that ICT provides universal education, transcending disciplinary boundaries. This directly interferes with the continuous initial training (FIC) of Mathematics teachers, so the "curricula of these programs must be revised to incorporate this new skill" (Reis, Barichello & Mathias, 2021, p. 56).

Mathematics teachers play a fundamental role in inclusive teaching and learning; however, they need knowledge far beyond the discipline and the specific needs of each student. Thus, FIC, along with the sharing of best practices, collaboration among training centers, an interdisciplinary approach in the workplaces of these professionals, and consideration of their knowledge (Nóvoa, 2022 & Tardif, 2014), are fundamental in addressing these challenges and enhancing the quality of Mathematics teaching.

The implementation of pedagogical practices for students with disabilities and their inclusion in Mathematics teaching require the disruption of traditional methods to meet the needs of these students. For this reason, the use of differentiated educational resources, including ICTs, serves as a pedagogical strategy that makes mathematical content more accessible and understandable. However, it is "a very complex job" (Santos, Vianna & Silva, 2024, p. 4) and requires more from the teacher.

The promotion of an inclusive environment, which contributes to the development of a more conscious, respectful, and supportive school community, must consider the teacher first and foremost, as they are trained to teach Mathematics to diverse audiences. However, the advent of ICTs in continuing education brought innovative opportunities to students with disabilities.

3 Methodology

In this study, a qualitative exploratory approach was adopted, with the participation of seven students. Three attend the first year of high school, while the remaining four are enrolled in the 3rd year of the Technical Management Course at the Integrated Campus of Basic, Professional and Technological Education (Ciebtec), with which GPTDEM has a partnership to promote awareness of inclusion.

The students underwent training on the functionalities and use of the Lego Mindstorms EV3 platform and Arduino. The meetings took place in the auditorium due to the availability of internet access (Fig. 2). Initially, it was explained that the construction of the prototypes and the game would focus on inclusive education, considering the students from the Grapiúna Pedagogical Support Center (Centro de Apoio Pedagógico - CAP) and colleagues at Ciebtec. In addition to the problems raised by the students, others were presented as a way to enhance creativity in developing proposals that would facilitate mathematical learning and accessibility for students with disabilities. Smartphones, chromebooks, and laptops were used to build the prototypes and the game.

A semi-structured questionnaire was used for data collection. According to Marconi and Lakatos (2009), it is a direct and intensive observation tool, due to the way it collects data from research participants. Fiorentini and Lorenzato (2012) defend the importance of this tool for qualitative research, particularly when using open-ended questions, as it provides deeper and more nuanced analyses. The questions allowed us to explore in depth the effects of inclusive practices.

Figure 2: Students in the Auditorium Constructing Prototypes

Source: Research collection (2024).

Initially, the students proposed a prototype at random, without considering the requirements for including PwD in the school environment. However, they soon realized that, without the help of teachers and researchers, they would encounter difficulties. Strategies and methods for building the prototype were then presented, based on the identified problem. After these interventions, the prototypes of CAV, Lubotica and the game "Dê um up na inclusão" were developed independently by the students.

In this work, contributions were obtained through a questionnaire, with impressions about the use of robotics for inclusion, as well as research on CAV, Lubotica, and gaming for people with attention deficit hyperactivity disorder (ADHD) and autism. All of them are presented in the results and discussion section.

The excerpts from the contributions and the development of prototypes enabled understanding whether mathematics, associated with robotics and CT, would contribute to training students with an awareness of inclusion. Each action was based on the research group's observations and needs identified in the educational environment. In stage 1, the prototypes developed by the research group were presented. In stage 2, the participants shared their impressions and experiences regarding actions, learning, and contributions to the inclusion of PCd in the school environment.

4 Practice, Analysis, and Learning in Game and Prototype Construction

The following are discussions and reflections from seven participants, exploring topics relevant to this study and raising awareness for inclusive education. However, first, the prototypes developed during the research group's studies will be discussed, highlighting their contributions to understanding and interacting with students who have visual impairments, autism, and ADHD.

4.1 Educational Innovation and Inclusion through CAV, Robotics and the "Dê um up na inclusão" Game

First, the interface of Lubotica and the CAV is presented, as they are understood to be prototypes focused on the mobility of PwD, serving as instruments to promote inclusion.

The prototypes challenged the students to solve digital, social, and mathematical problems by creating games in the Game Maker program, where advancing through phases requires solving mathematical questions. The approaches, from the perspective of the learning methodologies (Moran, 2018), encouraged us to think about the potential of educational robotics for inclusion, as well as the benefits of ICTs for teaching Mathematics to PwD and their learning.

The games were designed to facilitate learning. As stated by Abreu and Andrade (2023, p.14), "the use of games in the classroom can contribute to a more stimulating and motivating environment, promoting interest and understanding of mathematical content". This approach makes it easier to create a more stimulating and motivating environment. The introduction of playful elements in the educational process can have a positive impact on student engagement, stimulating interest and understanding of mathematical content.

4.1.1 Interface between the CAV and Lubotica projects

The CAV and Lubotica projects were developed during the GPTDEM and UESC meetings, using technological tools such as Tinkercad, Arduino, and Lego EV3. The CAV project emerged from the need to include students as active participants in the school environment. In this scenario, the integration of ICTs into inclusive education offered much more than the reproduction of information, creating alternatives for understanding how information is processed and transformed into knowledge (Godoi & F. Silva, 2014; Rodrigues, Almeida & Valente, 2017; Valente, 2016). The focus of both projects was to investigate the development of prototypes from an inclusive perspective using educational robotics to promote student learning and interaction.

Thus, they became ways of propagating the scientific-technological character through action research within the educational environment, with ideas based on needs found in everyday school life (Vilhete et al., 2002), promoting student learning through skills and competencies proposed in the BNCC, in the era of Education 4.0 and with Generation Z. Silva (2023, p. 41) affirms that,

> faced with this new Education 4.0 scenario, ICTs prevail when the subject relates directly to the student; however, there must be integration of these technologies into teaching and learning, since Generation Z students have made teachers rebuild their pedagogical practices, both in the way they teach and in the way they learn.

Silva (2023) emphasizes the transformation of the educational landscape in the face of the advent of Education 4.0, marked by the prevalence of ICTs. In this context, students, especially those from Generation Z, play a central role, driving a reconfiguration of teachers' pedagogical practices (Nóvoa, 2022). The pervasive presence of ICTs in students' lives requires effective integration of these technologies into the teaching and learning process.

The CAV was built using the Lego Mindstorms EV3 educational robotics kit, consisting of a programmable block, a sensor array with motion, light, touch, ultrasonic, and sound sensors (Fig. 3).

Figure 3: Visual Aid Helmet Prototype

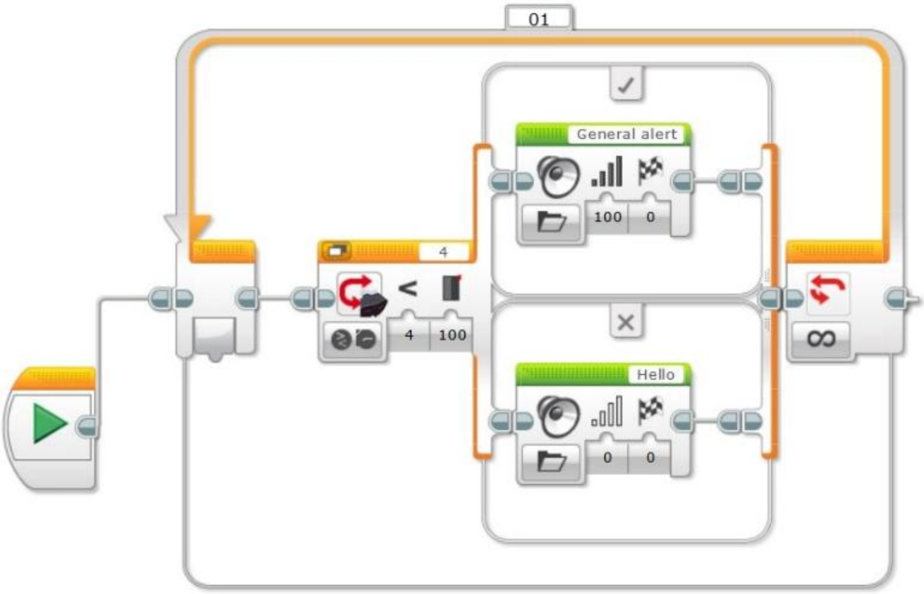
Source: Research collection (2024).

Then, its code (Fig. 4) was developed for the Lego Mindstorms EV3 platform.

The project emerged from observations within the school environment, with the aim of going beyond the development of the helmet by creating a sensory glove, the Lubotica, designed for this specific audience. The initiative reflected the vision that education must be inclusive, free from prejudices and disparities, placing students as active participants in the process.

Giraffa (2012, p. 22) defines students as "pioneering by nature," stating that "the current generation of adolescents has incorporated technological innovations much faster than their parents and teachers." The proposal to incorporate a sensory glove demonstrated the team's commitment to addressing the specific needs of this target audience. The inclusion of multiple devices suggests a comprehensive approach to providing innovative solutions that meet the demands and challenges faced by PwD.

Figure 4: Visual Aid Helmet Prototype

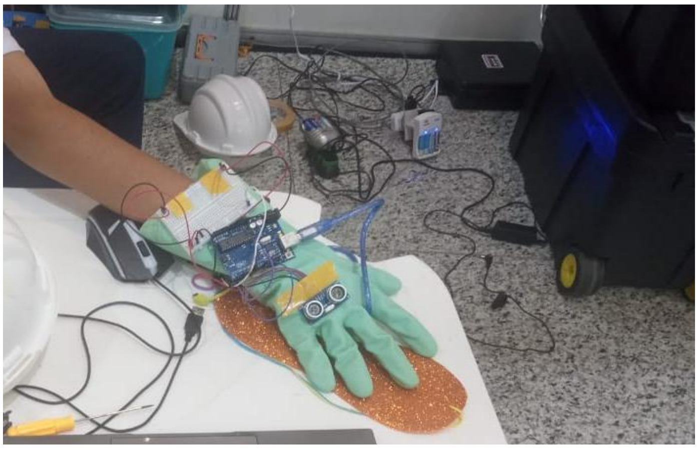


Source: Research collection (2024).

Lubotica was developed using Arduino, whose code is shown in Figure 5. To use the program Lubotica — Sensory Glove, the first step was to locate the program executable on the computer; then double-click on the icon to open a new window.

In the Lubotica prototype, the quality of the materials and the meticulous assembly of the device stand out. The essential components for this project include: Arduino board, HC-SR04 ultrasonic sensor, buzzer, long plastic tube, roll of electrical tape, and 9V battery with adapter for the Arduino board.

Figure 5: Lubotica — haptic glove



Source: Research collection (2024).

Table 1 shows the Lubotica code developed because it was understood that working with Arduino reduced costs.

Table 1: Robotics Code — sensory glove

Programming in C++

```
#define trigPin 7
#define echoPin 6
#define buzzerPin 11
void setup() {
 Serial.begin(9600);
 pinMode(trigPin, OUTPUT);
 pinMode(echoPin, INPUT);
 pinMode(buzzerPin, OUTPUT);
}
void loop() {
 long duration, distance;
 digitalWrite(trigPin, LOW);
 delayMicroseconds(2);
 digitalWrite(trigPin, HIGH);
 delayMicroseconds(10);
 digitalWrite(trigPin, LOW);

 duration = pulseIn(echoPin, HIGH);
 distance = duration / 58.2;

 if (distance < 30 && distance >= 20) {
 tone(buzzerPin, 1000);
 delay(500);
 noTone(buzzerPin);
 delay(100);
 }else if(distance < 19){
 tone(buzzerPin, 500);
 delay(500);
 noTone(buzzerPin);
 delay(100);
 }
}
```

Source: Research collection (2024).

Assembling the circuit required precise procedures to ensure the prototype's effective operation. Initially, connections were made between the Arduino board and the ultrasonic sensor, distributing power and establishing communication lines. The board's 5V pin was connected to the sensor's VCC pin, while the board's pins 7 and 6 were connected to the sensor's Trig and Echo pins, respectively. In parallel, the GND pin of the board was connected to the GND pin of the sensor. Still in the connection phase, the positive pin of the Buzzer was connected to pin 2 of the board, and the negative pin (GND) was connected to any GND pin on the board.

Once this process was completed, attention shifted to arranging the elements in the sleeve, considering ergonomics and ensuring that the wires did not interfere with the sensor's operation. The efficiency of the prototype is closely linked to the correct implementation of these steps, resulting in a device capable of emitting sound alerts when detecting nearby obstacles. The complexity of this construction requires technical and methodical approaches, considering not only the functionality of the components, but also the usability and effectiveness of the device. In this context, the Lubotic Sensory Glove represents a significant contribution to the autonomy and inclusion of visually impaired individuals, using technology as an ally in overcoming everyday challenges.

4.1.2 "Boost Inclusion" Game

Developed in GameMaker, the game's title screen is shown in Figure 6.

Figure 6: Title screen of the educational game

Source: Research collection (2024).

The proposed educational game was developed using Game Maker software, a versatile and accessible tool for this purpose. The construction process involved various steps, from conception to final polishing, resulting in an interactive and dynamic educational product.

In the early stages, free assets available online were used to create the basic structure of the game. Elements such as the spaceship, the background scenery, the shooting animation, and the question boxes were included in this phase, establishing the visual and conceptual foundation of the project.

In the next phase, programming was tackled, a crucial stage to provide the game with features and systems that would make it fully functional. Algorithms were then created to control the interactions, configure the buttons, manage the animations, and develop the question system. Additionally, accessibility options allow the player to disable time limits for answering questions and request help in case of an error.

In the game, the player takes control of a spaceship that develops defects to be repaired during its journey through space. The solution requires the correct mathematical questions to be displayed on the screen. These questions cover basic operations (addition, subtraction, multiplication, and division) and advance to roots, offering a progressive challenge to the player.

The questions appear on the screen accompanied by two answer choices, with one correct and one incorrect. The player, by controlling the ship, must select the correct answer and "shoot" at the chosen option. The time to choose the answer is limited to 15 seconds, with the option to turn off this restriction.

The game is structured in five levels, with phases 1 to 3 containing ten questions each, while phases 4 and 5 present only five questions. The difficulty increases progressively, culminating in the last phase. The player who completes all levels successfully finishes the game, demonstrating the educational and challenging nature of the project.

In summary, the educational game presents itself as a multifaceted initiative, aimed not only at providing tailored entertainment, but also at promoting social inclusion and enhancing cognitive and motor development. The approach centered on the specific needs of each individual reflects the commitment to offering an educational and fun experience that breaks down barriers, contributing to the creation of a more accessible and enriching environment.

4.2 Topic 1: Construction of Prototypes by Students

The student **Marcos** highlighted the introduction of a new programming system, the Lego Mindstorm EV3, for the construction of the CAV, comparing it to Ardublock. This aspect highlights exposure to innovative technologies and familiarity with different programming platforms. The speech reveals the student's successful adaptation to new programming methods, indicating a willingness to explore advanced technologies. "The experience I gained in constructing the CAV involved a new programming system using Lego Mindstorms EV3, where we programmed in a block programming mode somewhat similar to Ardublock, which I had not used as a system before".

The experience emphasizes the importance of offering opportunities to work with various programming systems. The diversification of learning environments can stimulate interest and curiosity, preparing students to face diverse technological challenges.

Student **Antony**[1], while favoring interactive games, especially "Dê um up na inclusão", pointed out a more playful and creative approach. The positivity expressed regarding the diversity of projects suggests that the educational experience was enriching and motivating. In his speech, he emphasized the importance of personalized approaches to learning, recognizing the variety of students' interests: *"I didn't participate as actively in the construction of the CAV; I focused more on interactive games. So, my experience was very positive. I had fun creating the project and I feel that I acquired very unique knowledge."*

The preference for interactive games highlights the need for flexibility in educational robotics projects. This shows that allowing students to choose projects aligned with their interests can result in greater engagement and satisfaction, contributing to more meaningful learning.

The student **Miguel** shared a humanitarian perspective, mentioning that he felt part of a larger project, with the potential to benefit others, in the construction of Lubotica and the CAV: *"I felt like I was part of a larger project that could help other people if it were expanded and improved."* His perception of being part of something bigger highlights the ethical dimension of educational robotics and underscores the importance of incorporating projects with social

[1] Pseudonyms were used to ensure the anonymity of the research participants.

impact, encouraging students to consider not only the technical aspects but also the ethical and humanitarian implications of their creations.

The student **Henrique** summarized his experience as "very good," emphasizing that he was satisfied with the construction of the CAV. This brief expression suggests enthusiasm for the project, indicating an emotional connection with the activity: *"The experience of constructing the capacete auxiliar visual (CAV) was very good"*. Its positive assessment highlights the importance of the emotional aspect in learning, which can contribute to motivating students and positively impact their persistence and quality of work.

Student **Ruan** describes the experience as challenging. This perception indicates an understanding of the project's complexity. The speech suggests an appreciation for the difficulty, highlighting the value of challenges in learning and personal growth. *"As challenging, something complex."* The appreciation of the challenge highlights the importance of projects that encourage students to tackle difficulties. This promotes a growth mindset, helping them develop problem-solving skills and the ability to overcome obstacles.

Based on the experiences gained in building the CAV prototype using simple elements, the student **Paulo** stated: *"My experience with the CAV prototype was very basic. I used a helmet as a base, along with adhesive tape, an infrared sensor, and a programmable board from Lego Mindstorms. I also created some games based on some ideas."* The simplicity of the materials used highlights the accessibility of robotics. Projects with common, low-cost materials provide opportunities for all students to explore robotics, regardless of available resources.

The student **Adriano** highlighted the experience as a way to discover "*new skills*", in addition to emphasizing the "*importance of group work*", as it demonstrates ways to enhance learning. The emphasis on group experiences highlights the importance of interpersonal skills in robotics learning. Collaborative work promotes knowledge sharing and allows the development of fundamental social skills.

Regarding the challenges in developing the prototypes, **Marcos** highlighted: *"The biggest challenges were the limited number of programmable boards, of which we only had two, and the batteries that ran out quickly."* Logistical challenges highlight the importance of providing adequate resources for educational robotics activities. The scarcity of equipment can negatively impact the project's progress, which requires solid infrastructure. Purchasing resources from specific sites with long delivery times can make it difficult to execute ideas in a timely manner.

From this perspective, **Antony** pointed out logistical obstacles related to the availability of resources, mentioning the need to use his brother's laptop at specific times. The importance of equal access to technological resources is highlighted, as Ciebtec made Chromebooks available for use only within the school environment. *"Mainly, I did most of the project on my brother's laptop, but I could only use it at night and on weekends (when he didn't need it), so this greatly delayed the initial development of the project."* The dependence on laptops indicates the need to provide individual resources to students and the importance of ensuring equal access to technologies necessary for projects.

An important point, mentioned by **Miguel**, regarding the complexity of the code as their main challenge, highlights the need for a detailed understanding of programming: *"The main challenges were the coding, because for me it was something new that I had never encountered before, especially when it came to EV3, because it was a type of block programming. I had to understand how it worked."* The complexity of the programming highlights the importance of providing adequate technical support. Robotics projects should include training programs for students to develop the necessary skills to overcome conceptual challenges.

Henrique, on the other hand, focused on the specific challenge of CAV programming, indicating the need for a detailed understanding of the language, which is expected to be structured in blocks: *"The CAV schedule"*. The emphasis on specific CAV programming indicates the importance of focused and in-depth approaches to specific technical aspects of each project. This suggests a solid understanding of the programming languages relevant to the success of the project.

Adriano highlighted the challenge of *"Visualizing the project before its construction as something that would really work and could be implemented"*. Thus, he emphasized the importance of providing tools and methodologies to assist students in designing and properly planning their projects, as well as the need to develop design and critical thinking skills.

4.2.1 Lessons Learned from the Robotics Project

In his reflections, **Marcos** highlighted the practical utility of robotics in creating projects that help other people, especially those with visual impairment: *"I learned that, with the use of robotics, we can create projects that can help other people, especially those who need assistance from external devices, such as the CAV itself, which helps visually impaired people to move around"*. The highlighted learning emphasizes the importance of robotics projects with practical applications and social impact, and highlights the relevance of educational robotics in developing students as conscious and responsible citizens.

Antony, on the other hand, emphasized the breadth of skills acquired: *"I feel like I've learned to develop games from start to finish. This includes the programming, art, direction, creation of a screenplay, development of songs, and improvement of my overall creative capacity."* The diversity of skills mentioned highlights the holistic approach to learning in robotics. Projects that involve different aspects, such as programming, art, and design, promote a more comprehensive understanding of the skills needed in the ICT field.

Learning programming in blocks and the need for research in various areas were emphasized by **Miguel.** *"I learned to program in blocks and conducted research in other areas."* This learning suggests the importance of integrating different approaches. The combination of practice and theory contributes to a deeper understanding of the concepts, and the relationship between theory and practice is important when working with educational robotics.

Programming was the focal point of **Henrique**'s learning, specifically with the use of the Lego EV3. *"The EV3 schedule"*. The focus on EV3 programming highlights the importance of addressing technologies relevant to the project at hand and the need to adapt the curriculum to the tools and languages used.

Ruan mentioned: *"Innovation, structure, research, and construction"*, indicating a wide range of competencies developed, which prepare students for the complex challenges of society. The variety of learning opportunities highlights the multifaceted approach of educational robotics.

Learning about Robotics provided **Adriano** with the understanding that there are new ways to develop and plan for the future. The student realized that technology is deeply ingrained in our lives and recognized that there is always something new to learn.

4.3 Topic 2: Project Evaluation and Future Perspectives

The exploratory research provided an in-depth analysis of students' perceptions regarding the results of the CAV, Lubotica, and the game, as well as their perspectives on the project. When evaluating the participants' satisfaction, it was observed that **Marcos** highlighted the humanitarian purpose of the project, stating, "I feel very happy because we created a project that will be used for the people who need it most. All three projects are very important, and that is very good." He highlights the importance of social impact in the positive perception of the project.

On the other hand, **Paulo** suggested that there is considerable room for improvement: *"I feel like I need to improve a lot."* This critical perspective points to the need for a continuous improvement approach, reflecting a reflective stance in relation to the results obtained. Additionally, **Adriano** shared: *"I'm very happy. It exceeded my expectations, and other people liked it, which made me really see the potential of the project."* This positive reaction was reinforced by the pleasant surprise of others, highlighting the importance of external validation.

Regarding future prospects and suggestions for improvement, **Antony** suggested increasing efficiency in the work process by mentioning: *"I just wish I had a better way of working."* The observation highlights the importance of optimizing development methods to achieve greater effectiveness.

Miguel addressed specific limitations of CAV and Lubotica when proposing: *"Expanding its capabilities would be ideal to improve the sound quality, visual effects, and reduce weight."* He highlights a practical approach to improvements, considering technical and functional aspects of the projects. **Paulo** contributed to the suggestions by proposing, *"CAVs with cameras at various angles and artificial intelligence that helps with mobility"*. This idea suggests a technological expansion of the project, highlighting the potential for innovation and advancement in the CAV's functionalities.

Finally, **Adriano** emphasized the importance of training the group by suggesting *"specialization courses, which could enhance the development and empower the group"*. This vision highlights the need to invest in continuous skill development, promoting an educational and training approach.

Thus, the combination of positive evaluations, constructive criticism, and suggestions for improvement reveals the complexity of students' experiences, providing a holistic view of the impact of projects and opportunities for future improvement.

4.4 Topic 3: Awareness of and Contribution to Inclusion

The students' perception of PwD reflects awareness of the need for specific assistance for this population Comments such as: "*People with disabilities need assistive devices to help them with their physical needs*" (**Marcos**) demonstrates a real understanding of the practical challenges faced by PwD. Students seem to recognize the existence of these individuals, as well as the importance of practical approaches to improving their lives. This initial perception reflects sensitivity to the difficulties they face, indicating an important empathetic basis. This understanding is crucial for creating effective inclusion solutions.

Emphasizing that they are often overlooked in terms of aid, **Antony** highlights the need for effective initiatives to improve their quality of life. By stating "*they need methods to help them integrate into society*," he emphasizes the importance of concrete actions and suggests a broader understanding of the physical limitations and social barriers that this group faces. This awareness of the social invisibility of PwD highlights the need for a more active approach to promoting inclusion, addressing practical challenges and overcoming social barriers through innovative projects.

When discussing ways to contribute to inclusion, **Marcos** highlighted the creation of prototypes as an effective way to meet physical needs, while **Antony** broadened this perspective, emphasizing the lack of initiatives to provide diverse experiences through gaming projects. This variety of approaches suggests a comprehensive understanding of the needs of PwD. The various proposals indicate an inclusive and creative approach for students, recognizing the diversity of PwD needs and the importance of personalized and adaptable solutions to enhance inclusion.

In addressing the contribution of robotics to the inclusion of PwD, **Marcos** and **Antony** see the opportunity to create prototypes that meet the specific needs of this group. **Miguel** highlights the role of robotics in scientific innovations and advancements, suggesting a pragmatic approach to improving quality of life. This highlights robotics as a versatile and adaptable tool for promoting inclusion.

Emphasizing the potential of the CAV and Lubotica prototypes, **Henrique** stated, *"Even though it is a prototype, it provides greater confidence in mobility,"* stressing the importance of considering, in addition to physical needs, the positive psychological impact of such innovations. Trust is identified as a key element in inclusion, particularly in the emotional dimension, when developing technological solutions.

Ruan emphasized the importance of *"artificial intelligence to meet the individual needs of PwD"* and pointed to personalization through AI as an effective strategy, highlighting the importance of adaptable and flexible solutions.

Paulo broadened the scope, addressing robotics as a *"facilitator in various areas of life for PwD"*. His holistic vision reflects a more comprehensive understanding of the various dimensions of these people's lives, going beyond mobility and pointing out the need for approaches that consider the various areas of need for PwD.

Adriano emphasized the importance of investing in research to offer practical and effective solutions, stating that *"a lot is said, but this often remains only on paper, and, in practice, there is no effective investment in real solutions"*. He emphasized the ongoing need for innovation and research to address the complex challenges of inclusion in educational robotics. This reinforces the importance of an evidence-based approach to developing sustainable solutions, since thinking about practices or prototypes to facilitate the mobility of PwD requires sustainable resources.

These discussions reveal technical ability in the development of the prototypes and a deeper awareness of the needs and possibilities of including PwD. The students' sensitive and innovative approach suggests inclusive thinking rooted in a genuine understanding of the experiences and challenges faced by this segment of the population.

In summary, this work highlights a variety of students' perceptions and proposals regarding PdC and the role of robotics in promoting inclusion. The discussions revealed concerns about potential solutions for creating an inclusive and accessible society.

5 Final Thoughts

In this article, an analysis of the use of educational robotics and a digital game developed in the GPTDEM and implemented with students from Integral and Technical High School was presented, with the aim of raising awareness about inclusion. The pedagogical potential and practices were presented from the perspective of the AM, with emphasis on the tools and technologies for thinking about teaching Mathematics for PwD and their learning.

Mathematics, in particular, is presented in a formal and traditional way, since, unlike other disciplines, it is often criticized for the prevalence of traditional methods in the classroom. With the advent of ICTs, whose use arrived in Basic Education indirectly, technological advances emerged to give meaning and purpose to the classroom.

Mobility difficulty is a problem faced daily by students with physical disabilities and their teachers, since interaction among peers contributes to the Mathematics learning process. Thus, understanding the school's reality is necessary to devise solutions to these challenges, as demonstrated by the construction of the prototypes and the game. In addition, these proposals contributed to making Mathematics classes more dynamic, as learning by doing is one of the ways to improve learning.

From this perspective, the research group's actions will enrich discussions about the use of educational robotics and CT in teaching Mathematics for PwD, as well as train students with an awareness of inclusion, since the game and prototypes related to Mathematics link the knowledge of the disciplines to everyday challenges. The proposals show that it is possible to develop thinking and raise students' awareness, through educational robotics, for inclusion. Despite the challenges presented by some students, when working as a team or in a group, knowledge is complementary and doubts and problems can be solved.

The contributions of educational robotics to education proved effective in teaching Mathematics for PwD, and the research and actions of the research group indicated that it was possible to achieve these objectives, as well as to raise awareness and train individuals capable of developing robotics adapted to inclusive education. GPTDEN's initiatives consolidate scientific advances and demonstrate a lasting commitment to inclusion and equality in the educational environment.

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