Introducing Machine Learning Through a Multisensory Approach for Young People with Down Syndrome

Lui Gill Aquini[1], Júlia Veiga[1], Tiago Thompsen Primo[1], Luciana Foss[1], Simone André da Costa Cavalheiro[1], Leomar Soares da Rosa Junior[1], Laura Quevedo Jurgina[1]

[1]Center for Technological Development – Federal University of Pelotas (UFPel)
Graduate Program in Computing (PPGC)
Pelotas – RS – Brazil

{lgaquini,jvsilva,tiago.primo,lfoss}@inf.ufpel.edu.br

{simone.costa,leomarjr,lqjurgina}@inf.ufpel.br

Abstract. *This paper presents an ongoing educational activity to introduce Machine Learning concepts to children and young people with Down Syndrome. In Brazil, the lack of a standard for Computer Science Education until 2022 led to disparities, with public schools often lacking resources. A 2022 regulation made Computing mandatory in K-12, aligning with the Brazilian National Common Curricular Base, which includes Artificial Intelligence-related competencies. In the Brazilian context, Computing is still not part of the school curriculum for most students without disabilities. Students with developmental disorders, such as Down Syndrome, have even less access to activities designed to teach computational skills in their learning environments. However, it is possible to observe that, when provided with technologies adapted to their needs, these students can learn and develop effectively. Therefore, this work proposes a multisensory unplugged activity tailored to introduce Machine Learning concepts to people with Down Syndrome. Given the multisensory approach, we expect to observe benefits beyond computational learning, promoting the development of fine motor skills through a playful and fun experience.*

1. Introduction

Computing Science Education has been gaining more space in school curricula worldwide, reflecting the growing importance of digital skills in contemporary society. In Brazil, the National Common Curricular Base (BNCC) is a document that organizes essential knowledge for Brazilian children and teenagers. In 2022, the Brazilian National Education Council approved a regulation making Computing mandatory in K-12. The proposal was based on guidelines developed by scientists and educators from all over Brazil, with the support of the Brazilian Computer Society, which outlines the competencies and skills to be covered at all educational levels. The BNCC is organized into three main topics: Computational Thinking, Digital World, and Digital Culture. The skills associated with these topics vary according to age group and include everything from an introduction to computational logic to developing projects with programming and automation. Artificial Intelligence (AI) is included in BNCC competencies, specifically in a high school skill, which requires students to understand the fundamentals of AI, compare it with human intelligence, and analyze its potential, risks, and limits [Brazil 2022].

DOI: 10.5753/sbie.2025.12590

The presence of AI in the BNCC highlights the importance of preparing students to critically engage with emerging technologies, enabling them to understand their impacts and explore their applications creatively and innovatively. However, implementing these topics requires methodologies that are inclusive and accessible to all students, regardless of their abilities and specific needs. In this context, accessibility in education becomes an essential element to ensure that all students, including those with intellectual disabilities, can benefit from Computer Science Education.

One such group is individuals with Down Syndrome (DS), a genetic disorder marked by the presence of three copies of the 21 chromosome. The syndrome presents problems in the areas of short-term memory and auditory and visual processing [Fidler et al. 2008]. In Brazil, 14 out of 1000 births are estimated to have this condition [Laignier et al. 2021]. In view of this high rate, it is necessary to develop educational activities designed for this audience. Significant learning gains can be observed in individuals with DS when personalized approaches address their specific needs. An effective strategy is the use of multisensory stimuli – such as touch, vision, and hearing – that optimize learning and support short-term memory and the development of fine motor skills [Acosta et al. 2024].

This work focuses on the 7 to 18 age group, as it represents a strategic period for literacy education for young people with DS. Cognitively, this stage is characterized by a strong aptitude for visual and concrete learning, which favors the systematic introduction of reading concepts through routine and repetition. At the same time, from a motor perspective, while hypotonia can challenge the development of fine motor skills, it is precisely within this time frame that targeted interventions can enable the physical act of writing. Therefore, the combination of continued cognitive plasticity with the opportunity window for motor skill enhancement makes this period ideal for building functional literacy, a cornerstone of individual autonomy and social inclusion [Boudreau 2002].

Following this approach, teaching AI to young people with DS requires methodologies that accommodate different learning styles, prioritizing multisensory strategies that encourage active participation and conceptual understanding. Methods that combine visual, auditory, and tactile elements can enhance learning, making AI concepts more concrete and accessible. Thus, developing inclusive pedagogical strategies for teaching AI not only expands these students' participation in the Computing field, but also reinforces the commitment to a more equitable and democratic education [Swargiary and Roy 2024].

There is still a lack of educational activities tailored to individuals with DS, particularly when it comes to teaching concepts related to specific topics such as Machine Learning (ML) – a branch of AI that enables systems to learn patterns from data and make predictions. Most available materials do not address the specific needs of these students, such as the need for more concrete, interactive, and multisensory learning approaches. Furthermore, the lack of teacher training in inclusive methodologies makes it difficult for teachers to adapt these subjects, leading to a reduced participation of students with intellectual disabilities in technology education [de Alencar et al. 2019]. The development of playful methodologies and the use of assistive technology could make these concepts more accessible, fostering digital inclusion and autonomy.

Therefore, this paper presents an ongoing activity aimed at making ML education more accessible to individuals with DS. The rest of this paper is organized as follows: Section 2 reviews related works and highlights the unique aspects of the approach presented in this paper, which combines multisensory and unplugged methods; Section 3 describes the methodology of the activity; Section 4 presents the final remarks and future work, discussing the evaluation of the activity, expected results, and the possibility of expanding the activity to other concepts; and Section 5 presents the acknowledgments.

2. Related Works

The teaching of AI in K-12 has attracted the attention of the academic community. Several studies have investigated pedagogical strategies, tools, and methodologies to integrate AI into the school curriculum. Considering ML, Vartiainen et al. (2020) investigated the integration of ML topics into K-12 using a design-based pedagogical approach. The study, conducted with 6th-grade students in Finland, aimed to develop and explore pedagogical models and tools for teaching ML, positioning students as co-developers of ML applications that solve everyday problems. The research showed that the co-design process of real-world applications reduced barriers to participation in core Computer Science practices and allowed children to explore abstract ML concepts in a personalized and contextualized manner. The authors observed that the students, by interacting with tools such as Google Teachable Machine, developed a deeper understanding of ML concepts, such as image classification and sound recognition, and demonstrated data-based reasoning skills. Additionally, the study highlighted the importance of hands-on and collaborative activities to engage students and promote data agency, preparing them for an increasingly data-driven world. The findings suggest that the co-design approach can be effective in teaching ML to children, fostering creativity and innovation while demystifying Computer Science.

Shamir and Levin (2022) investigated the feasibility and effectiveness of introducing ML concepts in K-12 using a constructionist approach. The authors developed two distinct courses: one focused on “learning ML by design”, where students built their own artificial neural networks, and another on “learning ML by teaching”, where students trained and validated pre-existing ML systems. The study involved 12-year-old students and assessed the development of their computational thinking skills through qualitative and quantitative methods. The authors of this work indicated that both courses promoted computational thinking competencies, but with significant differences: the “learning by design” group showed greater development of computational skills, while the “learning by teaching” group demonstrated improvements in computational perspective. The study suggests that building artificial neural networks can increase students’ motivation and understanding of ML, while data-focused activities can enhance specific computational practices. The paper concludes that integrating ML into the computational thinking curriculum is feasible and beneficial, offering pedagogical insights for future research and educational developments.

Regarding inclusive practices, using AI for teaching, Šumak et al. (2024) analyze the impact of AI-based tools in promoting inclusive education. The authors explore various technologies, such as intelligent tutors, chatbots, robots, adaptive learning systems, and automated assessments, highlighting how these solutions can enhance accessibility and personalize learning. The study identifies significant benefits, including personalized learning, increased student engagement, and support for students with special educational needs. Additionally, AI can reduce teachers' administrative workload, improve educational management, and facilitate the inclusion of students with disabilities.

Existing research demonstrates various initiatives aimed at integrating AI – and, more specifically, ML – into K-12 exploring different pedagogical strategies and tools to make these concepts accessible to students. In addition, AI-based approaches have been leveraged to foster inclusive education, provide personalized learning experiences, and support students with special educational needs. However, when it comes to introducing AI concepts to students with intellectual disabilities, particularly those with DS, existing proposals remain scarce. Our proposal stands out by addressing this gap with an approach designed for this audience, considering their cognitive and developmental characteristics. While previous studies have focused on methodologies for teaching ML that have not been systematically adapted to accommodate the particularities of students with DS, our activity integrates multisensory learning strategies, simplified conceptual models, and highly interactive experiences to ensure accessibility and engagement.

3. Our Approach

This section presents the proposed activity. Subsection 3.1 describes the methodological steps in its conception, while subsections 3.2 and 3.3 detail the proposed tasks. Each task presents a different type of ML using different stimuli: one stage focuses on vision and applying concepts related to *supervised ML*, while the other focuses on *reinforcement learning*. The latter incorporates tangible pieces to enhance fine motor skills and visual stimuli to indicate correct and incorrect actions.

3.1. Methodology

The study of ML involves several concepts, such as data representation, training and prediction, and decision-making in ML models. Given that the target audience for this proposal consists of students with DS, a gradual introduction to these concepts is more appropriate. According to Resnick (2017) , activities should be initially designed with simple objectives and accessible tools (low floor) while also allowing expansion to incorporate more complex concepts (high ceiling). In this context, the methodological steps adopted in this proposal were the following.

1. **Theme Selection:** we selected a theme that would engage the target audience. Our goal is to develop a skill from the BNCC with children and young people with DS. Therefore, the educational activity is designed as an interactive learning experience that introduces fundamental concepts of ML to this audience. In this activity, students will help a robotic dog complete challenges that involve *supervised learning* and *reinforcement learning*, such as recognizing objects, responding to commands, and making decisions based on rewards and feedback. This playful approach to the AI agent enhances the abstraction of a complex component, allowing the student to associate it with a representative that evokes empathy and connection.
2. **Concepts Introduced in the Activity:** identifying the key concepts to be introduced. The activity will be designed in stages, each addressing different ML models. The first stage will focus on concepts related to *supervised ML*, including data collection, model training, and accuracy, while the second stage will cover concepts related to *reinforcement learning*, such as rewards, penalties, and gradual

learning. The subsequent stages will address concepts related to *unsupervised learning*. For each stage, the following steps will be followed:

(a) **Initial Task Design:** this task will cover the fundamental concepts necessary for understanding the model under consideration.
(b) **Comprehensive Task Design:** designing a task that integrates all key concepts of the model under consideration.
(c) **Task Implementation:** putting the previously designed tasks into practice, using both digital and physical resources.
(d) **Pilot Case Study:** applying the implemented tasks to a group of students with DS to identify potential issues and challenges, as well as to assess understanding of the introduced concepts.
(e) **Redesign:** based on the results obtained in the pilot case study, the adjustments to the tasks will be analyzed.
(f) **Case Study:** a case study will be conducted with students with DS to evaluate the effectiveness of the entire stage related to the model under consideration.

In this work, we focus on *supervised ML* and *reinforcement learning*. The activity is currently in step (c). A description of steps (a), (b), and (c) is presented in Subsections 3.2 and 3.3, while steps (d)-(f) are planned for future work.

3.2. Supervised Machine Learning

To introduce *supervised ML*, we plan to design an interactive comic book. In this engaging narrative, students follow an AI agent tasked with solving a specific problem. Along the way, they face a challenge: they must collect data by identifying clues hidden within the comic panels. These clues act as labeled data that are essential for "training" the AI agent to reach an accurate solution. Through this immersive process, students gain hands-on understanding of how ML models learn from data to make predictions.

In this activity, the clues discovered in the panels simulate the data collection process used in ML. The more and better the clues that the students collect, the more effective the training process becomes, directly affecting the accuracy of the final solution. This approach not only demonstrates key *supervised ML* concepts, but also enhances problem-solving skills through interactive visual stimuli. In Figure 1, a comic book panel illustrates the character investigating clues, simulating the data collection process. In this scene, the student can observe that the footprints resemble a human's rather than a dog's. This information will later be used during the model training simulation, where students will understand that the more clues they identify while reading, the higher the accuracy of the final outcome.

This activity is designed to allow for the observation of key indicators in the target audience's behavior. Specifically, it seeks to evaluate the degree of engagement with the task, the participant's ability to verbalize their planned actions, and, crucially, their capacity to correctly associate each clue with its respective meaning within the training's logic. The purpose of these observations is to determine the effectiveness of the proposed multisensory approach.

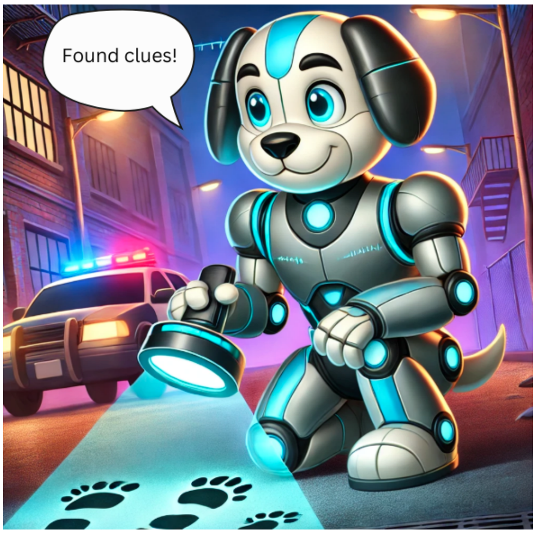

Figure 1. A scene in which the character analyzes footprints, representing the process of collecting labeled data for supervised model training.

3.3. Reinforcement Learning

In the second activity, the concept revolves around students actively exploring the concept of *reinforcement learning* by guiding an AI agent through a tangible maze board equipped with LED illumination. The student takes on the role of navigating the agent along a path, deciding which direction to take while collecting keys, and striving to unlock the exit of the maze. If the agent touches a wall, the student must restart the journey, directly experiencing the impact of penalties. As the agent moves, yellow LEDs illuminate the previously traveled path, providing immediate visual feedback that reinforces the idea of learning from past actions.

The professional who applies this activity acts as an active facilitator, providing tips and relevant information about *reinforcement learning* concepts, with the objective of instructing the student and helping them to assimilate the logic for solving the proposed problem. This activity introduces *reinforcement learning* concepts —rewards for collecting keys, penalties for hitting walls, and gradual improvement through trial and error. With the positions of keys and the exit changing with each run, students must adapt their strategies, reinforcing computational thinking and decision-making skills. Additionally, by controlling the agent's movement, they enhance their fine motor coordination while witnessing first-hand how iterative learning leads to better performance. In Figure 2 is presented the concept of the board described on the *reinforcement learning* activity.

4. Final Remarks

This paper presented an educational activity designed to introduce ML concepts to children with DS through a multisensory approach. The activity integrates visual, tactile, and auditory elements to create an engaging and hands-on learning experience. To ensure the effectiveness of the developed activity, a comprehensive evaluation will be conducted with participants with DS, assessing not only their understanding of ML concepts, but also their engagement, retention and overall experience with the multisensory methodology.

It is expected that the activities, by associating visual cues with the agent's deci-

Figure 2. A representation of the board used in the reinforcement learning activity, featuring switches, indicator LEDs, and the agent's movement path.

sions and through the guidance of the professional supervising the sessions, will foster an understanding of the cause-and-effect relationships present in supervised and reinforcement learning models.

Currently, the necessary materials for the activity, such as the comic strip and the physical game board, are being developed in preparation for an initial performance test. The evaluation protocol is also being developed, and the first test will be based on the researchers' structured observation during the activity's execution. Following the activity, a second test will be conducted in the form of individual interviews with each participant. The objective of these interviews is to gauge their understanding of the material covered. The findings gathered will be crucial to making improvements to the proposed materials. The expectation is to conduct this initial test with a group of at least eight young people, covering a spectrum of ages within the target audience.

5. Acknowledgements

This work was supported by CAPES – Brazil – Financing Code 001, PREC, and PRPPG/UFPel. During its preparation, the authors also used generative AI tools for the creation of the figures and English spelling correction.

References

Acosta, V. A. C., Lalama, D. N. C., Guanoluisa, W. G. Q., and Barroso, S. A. Q. (2024). Enhancing social inclusion through multisensory stimulation: Improving fine motor skills in children with down syndrome. *Ibero-American Journal of Education & Society Research*, 4(1):118–128.

Boudreau, D. (2002). Literacy skills in children and adolescents with down syndrome. *Reading and Writing*, 15:497–525.

Brazil (2022). Computação: Complemento à bncc. `http://portal.mec.gov.br/docman/fevereiro-2022-pdf/236791-anexo-ao-parecercneceb-n-2-2022-bncc-computacao/file`. Accessed: 9 Jun 2025.

de Alencar, G. P., Campos, E. V., Pinto, V. P., Gonçalves, J. L., de Moraes Ovando, R. G., et al. (2019). Inclusion of students with down syndrome in brazilian schools. *International Journal for Innovation Education and Research*, 7(11):1290–1300.

Fidler, D., Most, D., and Philofsky, A. (2008). The down syndrome behavioural phenotype: Taking a developmental approach.

Laignier, M. R., Lopes-Júnior, L. C., Santana, R. E., Leite, F. M. C., and Brancato, C. L. (2021). Down syndrome in brazil: Occurrence and associated factors. *International journal of environmental research and public health*, 18(22):11954.

Resnick, M. (2017). *Lifelong kindergarten: Cultivating creativity through projects, passion, peers, and play*. MIT press.

Shamir, G. and Levin, I. (2022). Teaching machine learning in elementary school. *International Journal of Child-Computer Interaction*, 31:100415.

Šumak, B., López-de Ipiña, D., Dziabenko, O., Correia, S. D., de Carvalho, L. M. S., Lopes, S., Şimşek, İ., Can, T., Kline, D. I., and Pušnik, M. (2024). Ai-based education tools for enabling inclusive education: Challenges and benefits. In *2024 47th MIPRO ICT and Electronics Convention (MIPRO)*, pages 472–477. IEEE.

Swargiary, K. and Roy, K. (2024). *AI Angels: Empowering Children with Special Needs through Artificial Intelligence*. scholar press.

Vartiainen, H., Toivonen, T., Jormanainen, I., Kahila, J., Tedre, M., and Valtonen, T. (2020). Machine learning for middle-schoolers: Children as designers of machine-learning apps. In *2020 IEEE frontiers in education conference (FIE)*, pages 1–9. IEEE.