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COMPUTATIONAL THINKING TRAINING USING PICTOBLOX: EXPLORATORY STUDY WITH STUDENTS OF PRIMARY DEGREE

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ABSTRACT

PictoBlox is a graphical programming software based on Scratch, where interactive games, animations, or program robots and projects can be made. This paper presents an exploratory study on artificial intelligence context using PictoBlox to support the development of computational thinking and the ability to solve problems in primary degree students. The study involved twenty primary school students from a private school in northern Portugal on a didactic proposal that explores problem-solving using PictoBlox. The study was a qualitative and quantitative investigation which aimed to understand how artificial intelligence with PictoBlox can promote students' engagement in solving real situation problems using concepts and ideas from computer science. Findings suggest that students are receptive to exploring artificial intelligence with PictoBlox, get involved in solving problems using concepts and ideas from computer science, admit advantages using PictoBlox to express solutions to those problems. Furthermore, the initiative positively impacted participants' computational thinking skills, which was significant for those learners who initially showed less familiarity with this topic. Moreover, it was an enriching activity for the students that led them to solve problems in a fun way. A didactic proposal that promotes problem-solving using concepts and ideas from computer science and computational thinking in primary degree students based on graphical programming software.

KEYWORDS

Computational Thinking, PictoBlox, Problem Solution, Artificial Intelligence, Project-Based-Learning

1. INTRODUCTION

Computational thinking (CT) is the term used to describe students' knowledge of finding computational solutions to problems, algorithmic thinking, and coding. Computational thinking focuses on the skills that students develop through practice in programming algorithms, on the development of abstract thinking, the ability to solve problems, pattern recognition, and to be able to reason logically (Wing, 2006). Computational thinking skills are becoming essential in all aspects of people's work and lives (Wei, Lin, Meng, Tan & Kong, 2021). However, pedagogical strategies that help students acquire skills related to CT effectively, are still in the early stages compared to other disciplines such as math and sciences (Mishra & Kohler, 2006; Wei *et al.*, 2021). At present, information age students are receptive to the use of technology (Cruz, Bento & Lencastre, 2020), so it improves problem-solving skills, CT, and the ability to think logically. The goals that guided the research were to understand how artificial intelligence (AI) with PictoBlox can promote students' engagement in solving real situation problems using concepts and ideas from computer science.

The article introduces computational thinking and briefly introduces AI with PictoBlox as a graphical programming software based on scratch language. Then we present the methodology adopted in the exploratory study, and its description. Finally, we present a discussion of the results and main conclusions. It ends with some proposals for future investigations.

2. CONCEPTUAL FRAMEWORK

2.1 Computational Thinking

Computational Thinking (CT) is a cognitive ability enabling people to develop computational solutions for a current problem (Wing, 2006). It is the process involved in formulating a problem and expressing its solution so that a computer can carry it out (Tabesh, 2021). Teaching CT can improve students' analytical skills (Relkin, Ruiter & Bers, 2021). Computational thinking allows us to take a problem, understand it and develop possible solutions. Then, we can present these solutions in a way that a computer, a human, or both, can understand (Wing, 2006). CT is a hybrid of several other modes of thinking such as logical, abstract, algorithmic, constructive, and modeling (Voskoglou, 2021). CT has been recognized as set of understandings and skills required for new generations of students (Rodríguez, Cawanga Cambinda, Bender, Avello-Martínez & Villalba-Condori, 2021). Therefore, CT is essential for every person, so it should be taught and acquired in early education (Hooshyar, Pedaste, Yang, Malva, Hwang, Wang, Lim & Delev 2021). The pillars of computational thinking are the decomposition process, the abstraction process, the recognition of pattern process, and the algorithm. During the problem-solving process, the CT comes into play when the problem is broken down into smaller subproblems, the attention focused on the essential characteristics, the knowledge of similar problems solved previously or an action plan to be elaborately executed (Fernández, Zúñiga, Rosas & Guerrero, 2018). The key to success in the twenty-first century is to combine hard and soft skills tailored to specific needs, including applying creative and innovative solutions to solve problems and applying new knowledge and skills in new settings (Short & Keller-Bell, 2021; Tabesh, 2021).

Wei *et al*. (2021) in a study, intended to examine the effectiveness of partial pair programming in developing CT in elementary school students. These authors obtained results that indicate that using Partial Pair Programming is a practical pedagogical approach to improve students' CT skills. In their longitudinal study, Relkin, Ruiter, and Bers (2021) examined changes in CT skills in first and second-grade students exposed to a developmentally appropriate coding curriculum. During seven weeks, they engaged students in learning activities that integrates programming and literacy concepts. These authors noticed improvements in children in the domains of CT which included algorithms, modularity, and representation. In addition, the children who learned to code improved in solving unplugged problems.

2.2 Artificial Intelligence with PictoBlox

PictoBlox is a graphical programming software based on Scratch and block programming methods (Manining & Singh, 2021), a platform built for block-based coding and AI education. PictoBlox is multi operating system (Windows, macOS, Linux, Android), and it’s free, so that people of all ages can use with different skills. PictoBlox allows students to integrate creativity in storytelling, games, animation, machine learning, or AI activities, for example. With this software, students can program their projects and collaborate and share their projects online. Thus, it can be used across all curricula to integrate technology in interdisciplinary projects and promote 21st-century students using technology. Unfortunately, teachers cannot monitor what students are creating, and so the student may use inappropriate material that the teacher would not know of until they review the project.

Voskoglou (2021) characterizes AI as a branch of Computer Science that focuses on creating intelligent machines to imitating typical human behavior and reasoning. According to this author, some machines, computers, robots, and various other mechanisms and methods of AI have already replaced humans in an increasing number of routine jobs. The more significant the AI is, the more pressing the need to understand it (Yang, Ogata, Matsui & Chen, 2021). Therefore, the inclusion of AI in education has been pointed out as a cornerstone to enable the adoption of AI in society (Rodríguez-García, Moreno-León, Román-González & Robles, 2021). The use of AI to diagnose learning conditions, for example, could enable teachers to intervene to enhance students' learning outcomes (Yang *et al*., 2021). Also, artificial intelligence labs can engage students in computational thinking skills training (Tabesh, 2021). PictoBlox has various extensions related to hardware, robotics, AI, and Machine learning. PictoBlox's AI extension allows you to carry out computer vision, facial recognition, optical character recognition, or speech recognition projects. Exploring

PictoBlox's AI extension area of computer vision can identify celebrities, landmarks, and objects in images. Exploring PictoBlox's AI extension area of facial recognition, it is possible to determine age, gender, and emotion from a face recognized in the pictures. Exploring PictoBlox's AI extension area of optical character recognition, it is possible to dent text in images and exploring the area of speech recognition. It is also possible to generate text from speech. In the following figure, we present the PictoBlox AI Extension coding blocks.

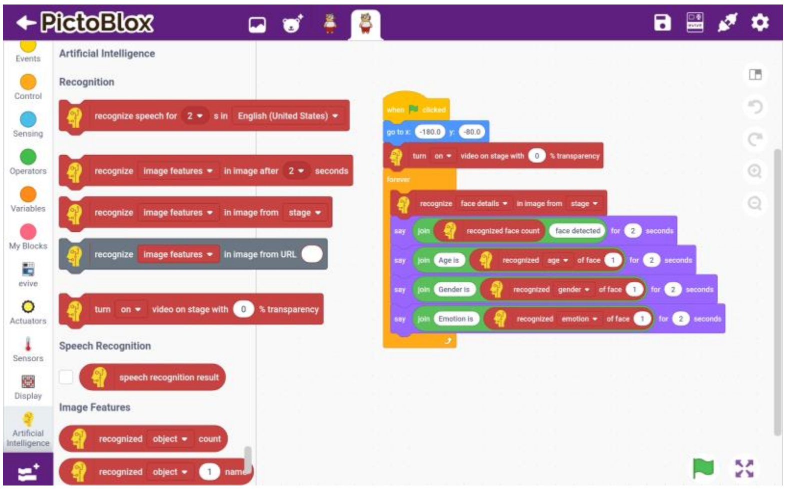

Figure 1. Example of PictoBlox algorithm with AI blocks

3. METHOD

This study took place during six weeks, of the COVID-19 pandemic, where classes took place in person but with strict safety rules to avoid contagion between the participants. This work's main objective is to understand how AI with PictoBlox can promote students' engagement in solving problems using concepts and ideas from computer science and expressing solutions to those problems to be run on a computer. We intend to build a new paradigm in the teaching and learning process to promote students' engagement in solving problems using concepts and ideas from computer science. To assess the computational thinking skills knowledge, we created a test that includes different kinds of questions based on previous investigations and publications, resulting in a reliable assessment instrument, according to Rodríguez-García *et al.* (2021). The intervention involved 20 students from the primary degree of a school in the region of Portugal. We articulated the activities based on the project-based learning methodology to engage students in real situation problems. Then, the students worked on the projects in small groups. To divide the class into small groups, we asked students about their preferences in terms of work topics, and PictoBlox software was to program the response code. Project-based learning is a student-centered methodology that develops skills and knowledge through studying, solving problems, seeking answers, and conducting research (Larmer, Mengendoller & Boss, 2015). So, students raise hypotheses, conduct research, and take practical actions until reaching a solution or product (Vargas, Ortiz, Pueyo & Rodríguez, 2019). Project-based learning is an active methodology that engages students in real-world problems, so it is the pedagogical methodology promising in the digital age (Duke, Halvorsen, Strachan, Kim & Konstantopoulos, 2021). Project-based learning promotes essential skills for 21st-century learners, such as solving problems and critical thinking. It is an active methodology that encourages responsibility, peer work, self-confidence, managing time, and communicating with other individuals (Larmer, Mengendoller & Boss, 2015).

Twenty students at a Portuguese school (8 females and 12 males) aged between 10 and 12 participated in this study. Most students showed a taste for challenges, despite some difficulties in solving problems. None of the students knew about PictoBlox before our research. Initially, students did not mention experiences previously with AI. It was noted that all students had access to 1:1 mobile device (Chromebooks), and most students had access to a computer at home.

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In our method, a student is a protagonist in the learning process, and the teacher is a facilitator, just managing the project. Students are encouraged to make their own decisions, choosing the best way to complete the tasks. Thus, students develop autonomy and act independently, requesting the teacher's help to clarify doubts. In addition, students were encouraged to develop critical thinking and skills such as creativity, collaboration, and communication to make the right choices and review the options chosen throughout the process. In our study, we guided students through the following procedure:

Step 1, students made a knowledge diagnosis;
Step 2, students identified and analysed the problem;
Step 3, students investigated solutions to solve the problem;
Step 4, students collected resources and trained a machine to learn from data;
Step 5, students tested solutions on PictoBlox and reviewed code when necessary;
Step 6, students solved the problem and applied their knowledge to the new case;
In step 7, students made a final reflection about the process.

We promote students' problem solving using 1:1 mobile device (Chrome-books) in an activity involving AI with PictoBlox with children of a primary degree from the Google Reference School in Portugal. The children were challenged to solve problems using PictoBlox using AI and block programming. The process was mediated by the Google Classroom platform, which is a web-based platform, and PictoBlox, which supported all phases of the process described above to communicate with students.

Different methods were applied to collect the data: (i) system logs on the platform, (ii) a diary to collect direct observations, (iii) a diagnostic and final test (iv) a final reflection through the final focus group with the students to get a qualitative assessment and to understand their perceptions about the process. The diagnostic and final test is made up of similarly divided questions involving knowledge of the decomposition process, the abstraction process, the recognition of the pattern process, and the algorithm. To code the students' responses, we use the designation Si for student i, with i = 1,…20. The final focus group was subjected to a qualitative analysis of the data, which allows describing the data (Bogdan & Biklen, 1994), understanding and interpret the participants' responses in the context (Coutinho, 2014). For this focus group analysis, we considered two dimensions: solve the problem process and use AI with PictoBlox.

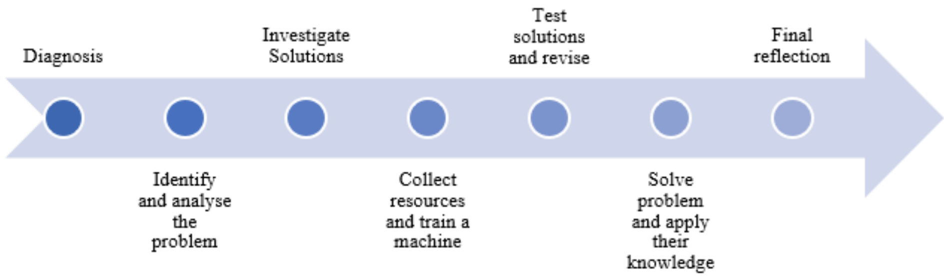

Figure 2. Our Process

4. RESULTS

The diagnosis showed that students recognize an algorithm but cannot define it as a set of instructions to solve problems and have difficulty exemplifying it. It showed that abstraction is also a common difficulty for students, who demonstrated trouble dealing with the issues' complexity. Cruz, Lencastre, and Coutinho (2015), in their study with teachers from STEM (Science, Technology, Engineering, and Mathematics) areas, also noticed that the ability to abstract is a difficulty commonly pointed out by many teachers in their students. Students with less experience in developing skills related to computational thinking showed more difficulty in decomposing as a process for defragmenting problems into small parts. However, pattern recognition was the area where students were most familiar, most recognized similarities and characteristics to solve problems. From the initial diagnosis to the end, we found that everyone improved some aspect. We presented the scenario of the problem to solve, and the students identified the facts, generated hypotheses individually or in groups, and answered questions essentially by video call. A comparative analysis of the initial and final score test was made for each student to analyse the evolution. Figure 3 presents a graphic chart of one of the students in the study, making it easy to identify individual progress in the areas (algorithm, decomposition, abstraction, and pattern recognition).

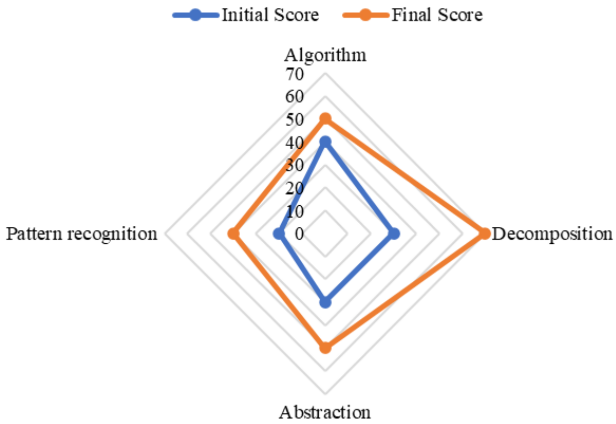

Figure 3. Comparison of S9 results

All students were organized into groups of two students. In step 1, students solved the initial knowledge diagnostic, and in step 2, students identified and analysed the proposed scenario. Then, students were challenged to create a program on PictoBlox that distinguished rabbits and cats through an image. Some students mentioned that "*initially I didn't understand what to do*" (S11), but after explaining with the workgroup, they went to step 3, where they investigated solutions to solve the problem. In step 4, students searched online recourses to train a machine to learn from data and collect different images of rabbits and cats. The collection of online resources is done through the Google search engine. The trained machine is made using the Teachable Machine in step 4. The Teachable Machine is a web-based tool that allows the creation of custom machine learning models, and it is accessible through the link teachablemachine.withgoogle.com. In step 5, students built the code in PictoBlox to create a project that allowed each image to identify whether it was a cat or a rabbit. At this stage, the students tested the code, clicking on the flag and seeing if the solution found on PictoBlox corresponded to what they intended. Finally, students reviewed the code, called the teacher if they had doubts about the created algorithm, and updated the code if necessary. In step 6, students applied their knowledge to the real-world case, solved the problem, and presented their project to the teacher and other classmates. The students who sought help wanted to know, essentially, why the code was not responding as they intended, about AI blocks, and errors on reading some of the images. In this stage, students had a diagnostic quiz to compare with initial quiz to highlight the evolution. In step 7, students make an oral reflection on the work developed.

From the work developed, we realized that understanding and enthusiasm for applying their knowledge to the real-world case is reinforced by individual involvement in executing the group's tasks. In PictoBlox, the students added the model created in the Teachable Machine and built the code to solve the problem through AI. We realized that integrating AI with PictoBlox by the students themselves motivates them to solve the issues presented. At the end of the process, students reflected on the advantages and difficulties they encountered in the process. All admitted that they enjoyed performing the proposed activity, felt that "*it was a challenge*" (S5) that led them to "*do it differently*" (S9). Our students were used to creating projects in Scratch, but the experience of training the machine to recognize the image excited them. At the end of the process, students reflected on the process, and we present the students' responses in the final focus group below (Table 1):

Table 1. Categories of analysis from student responses in final focus group

Dimension	Student
Solve the problem process	"*It was a challenge to organize the ideas and then put them in the code*" (S1). "*The most interesting thing was to test and see if it worked*" (S4). "*Yes, it was nice to research the images, learn to create algorithms with the new red blocks and also think about how to connect the pieces to give what the teacher asked for*" (S5). "*It was nice to learn how to create algorithms with the new red blocks and also think about how to connect the pieces to give what the teacher asked for*" (S6). "*It was fun to learn how to create algorithms with the new red blocks and test ideas*" (S8). "*I liked everything, I started to come up with ideas and I would see if it worked in the code when it didn't, we called the teacher*" (S9). "*It was cool to teach the machine to know what a rabbit and a cat are, and I also liked to organize the code to answer the problem or revise the code with the teacher's help*" (S10). "*What I liked the most was organizing the code and being able to solve the problem*" (S11). "*It was interesting to solve the code problems with the teacher's help and see that the result*" (S12). "*I just experimented until it worked. It was fun when I managed to get the images to work*" (S14). "*It was nice to see the code programming answering*" (S17).
AI with PictoBlox	"*PictoBlox is not confusing*" (S1; S6). "*I found it is simple to work with scratch-like blocks*" (S3). "*PictoBlox has simple and easy to connect commands"* (S2). "*I found PictoBlox easy because I had experience with the scratch app*" (S5). "*I found it quite easy to use and very simple too, as the blocks are evident, and I was able to explore the tool without any difficulty*" (S7). "*I found it easy and understandable*" (S9). "*I liked PictoBlox because it has obvious programming commands and it's very explicit and evident, and it's fun*" (S10). "*I liked it because it has simple commands, and it was fun working with the images"* (S11). "*I loved working with PictoBlox. I thought it was cool*" (S12). "*I already know how to work from scratch, and PictoBlox is similar. I found it easy to work and practical*" (S13). "*It was easy to work with the AI blocks*" (S15; S16). "*It was fun to work with because it had easy commands*" (S17). "it's *simple to build the code*" (S18). "*It was useful and fun to work with the new blocks to be able to say what we wanted in images*" (S20).

Of the twenty students, seven reported that the activity involving artificial intelligence with PictoBlox is strongly approved for the activity involving artificial intelligence, and the remaining thirteen reported that it is approved. They considered that PictoBlox "*is not confusing*" (S1; S6), it is a software that "*it is simple to work*" (S3) with that presents "*simple commands*" (S2; S7), "*like Scratch*" (S13) that they already knew. For this group of students, the PictoBlox blocks "*are obvious*" (s7), "*evident, and it's fun*" (S10) to program with their unions. Furthermore, students found it fun to work "*it was fun working with the images*" (S11) because "*it was cool*" (S12) to "*work with the AI blocks*" (S15; S16). Regarding the process of solving the proposed problem, the students considered that "*it was a challenge to organize the ideas and then put them in the code*" (S1). Students demonstrated the ability to identify the real-world case or which the process and solution were not known in advance. They admit that "*it was nice to research the images, learn to create algorithms with the new red blocks and think about how to connect the pieces*" (S5) for "*being able to solve the problem*" (S11). Problem solving is also the ability to determine a solution, build it, and implement it effectively. In general, students "*experienced until it worked*" (S14) while coding the construction of the algorithm in the PictoBlox to "*see the final result*" (S12) expected to solve the problem.

5. DISCUSSION AND CONCLUSION

The participants completed all phases of the learning experience, which due to the COVID-19 pandemic, had to be performed with distance restrictions among students. Programming contributes to developing skills related to digital literacy, computational thinking, and crosscutting each subject's curriculum. Our students were already quite familiar and autonomous in using the programming language in Scratch, but they did not know PictoBlox and had never used AI before. In this exploratory study, we wanted to understand the pedagogical relevance of AI with PictoBlox to engage students to solve real situation problems using concepts and ideas from computer science. Findings suggest that students are receptive to explore AI with PictoBlox, solve problems using concepts and ideas from computer science, and admit advantages using PictoBlox to express the solution to the problem presented. It was an enriching activity for the students, that led them to solve problems in a "*fun way*" (S8; S11; S14; S17; S20). The results suggest that AI with PictoBlox is relevant to involve students in solving problems and exploring ideas using computer science. Our results are in line with those found by Duke *et al*. (2021). These authors carried out a study investigating the impact of project-based learning with professional development supports on social studies and literacy achievement and motivation of second-grade students. The results were positive and showed sufficient evidence to continue implementing Project-Based Learning to foster learning by tapping into students' drive to connect with and make sense of their social world.

CT is seen to apply computer science's reasoning processes to STEM domains and apply to different problems and activities in everyday life (Wang, 2016). Using the PictoBlox programming language, students solve the problem, using concepts and ideas from computer science, and expressing solutions to those problems. In our process, students identified the real-world case, analysed the problem, investigated solutions to those problems so that they can be run on a computer, solved the problem, identified resources, and trained a machine to learn from data. In the next stage of the process students "*tested the solutions*" (S8), "*revise the code*" (S10) and modify their code to create custom projects. Finally, students solved problems using concepts and ideas from computer science, using their knowledge of the real-world case and presented the solution found to the other colleagues. These results align with the one mentioned by Tabesh (2021), as to this author, the *use-modify-create* framework offers a helpful progression for developing CT by students over time. According to this author, this framework allows engaging youth with progressively more complex tasks and increases ownership of their learning. Also, Wei, Lin, Meng, Tan, and Kong (2021), in a study that was to examine the effectiveness of partial pair programming on elementary school 171 students' CT skills, students discussed and reflected on the development of their work through Google Hangouts, shared the artifacts created with other classmates through the Google Classroom Platform. All students, which programmed in peer groups, completed the requested tasks and expressed solutions to solve problems presented and run them on a computer. We realized that while creating these projects, students learned to think critically and creatively, work collaboratively, and developed the ability to solve problems using computational thinking resources. We intended with this exploratory study to foster the student's curiosity to express solutions to those problems to be run on a computer. The results suggest that students improved their CT skills. Our results align with those found by Relkin, Ruiter, and Bers (2021), who also suggest improvements on algorithms, modularity, and representation in their children's study. As in our study, Relkin, Ruiter, and Bers (2021) found that young children who learned to code solved unplugged problems not explicitly taught in the coding curriculum. The students can engage in essential aspects of computational thinking within a learning environment, using artificial intelligence labs to solve problems and create original products (Tabesh, 2021), crucial skills for 21st-century students (Hooshyar *et al*., 2021; Rodríguez *et al*., 2021). With this exploratory study, we could place students' learning at the center of the pedagogical process and naturally develop their digital proficiency. With this work, we presented a didactic proposal that promotes problem-solving using concepts and ideas from computer science and the development of computational thinking in students of a primary degree based on graphical programming software. We suggest that PictoBlox can be seen as a promising platform for teaching and learning AI in primary degree environments based on these results. In addition, researchers and educators can use our learning process to promote computational thinking skills in the primary degree. This research proposes a model for developing CT using AI with the PictoBlox, creating a method to solve problems using concepts and ideas from different curriculum content. Due to the need to use varied information, it can be said that this is an interdisciplinary methodology since problems and solutions hardly involve issues of a single nature. This way, students need to use skills, knowledge, and content from different academic areas to solve problems. So, the proposed learning process seems to have the potential to inform research on interdisciplinary learning environments. However, it would be essential to have more research to understand the pedagogical relevance of AI with PictoBlox to engage students to solve complex problems about daily routines or problems that involve traditionally complicated concepts, like threshold concepts. It would also be interesting to see whether the involvement achieved with students in our work can be transferred to traditionally more complex subjects such as physics, chemistry, or mathematics.

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