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Computational Thinking in Elementary School in the Age of Artificial Intelligence: Where is the Teacher?

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ABSTRACT

Background: The term computational thinking offers a new approach in the field of cognitive science, through the premise of systematizing the steps of problem solving that it can be applied in Artificial Intelligence and to other sciences. **Objectives:** Offer to participants a continuous training in the context of computational thinking and evaluate the impact of understanding these teachers about their respective concepts and practices. **Design:** Of a qualitative nature, involving specific dynamics of action-research, the design of the teaching experience involves the elaboration of tasks, used as a teaching hypothesis, subject to reassessments and readjustments. **Settings and participants:** In remote context, through the Teams platform, with eleven primary and higher schoolteachers from Brazil, Portugal, Cape Verde and Angola. **Data collection and Analysis**: Data obtained through the recordings of the meetings and the proposals of the participants, analyzed according to the four phases of the reflexive spiral and the expansive cycle. **Results:** The contributions and involvement of the teachers were significant, and some proposals of activities conceived, two of them presented in this article. **Conclusions:** With the partial results obtained it is expected that the insertion of computational thinking in basic education develops skills of different abstraction, which helps children in solving problems in all areas of life, not only in the use of computers or for future computer scientists. The participants' proposals will be published and made available online, to contribute to teacher training in the context of computational thinking.

Keywords: Computational Thinking; Artificial Intelligence; Continuing Teacher Education; Elementary School

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Pensamento Computacional na Escola Básica na Era da Inteligência Artificial: Onde está o Professor?

RESUMO

Contexto: O termo pensamento computacional traz uma nova abordagem na área da ciência cognitiva com a premissa de sistematizar passos da solução de problemas que podem ser aplicados na Inteligência Artificial e nas demais ciências. **Objetivos:** Oferecer aos participantes uma formação continuada no contexto do pensamento computacional e avaliar o impacto da compreensão destes professores sobre seus respectivos conceitos e práticas. **Design:** De carácter qualitativo, comportando dinâmicas próprias da investigação-ação, o desenho da experiência de ensino envolve a elaboração de tarefas, utilizadas como uma hipótese de ensino, sujeitas a reavaliações e readequações. **Cenário e Participantes:** Em contexto remoto, pela plataforma Teams, com onze professores de escola básica e superior do Brasil, Portugal, Cabo Verde e Angola. **Coleta e Análise de dados**: Dados obtidos por meio das gravações dos encontros e das propostas dos participantes, analisadas segundo as quatro fases da espiral reflexiva e do ciclo expansivo adotado. **Resultados:** As contribuições e envolvimento dos professores foram significativos e algumas propostas de atividades foram concebidas, sendo duas delas apresentadas neste artigo. **Conclusões:** Com os resultados parciais obtidos espera-se que a inserção do pensamento computacional na educação básica desenvolva habilidades de abstração diferente, que ajude as crianças na resolução de problemas em todas as áreas da vida, não apenas no uso de computadores ou para futuros cientistas da computação. As propostas dos participantes serão publicadas e disponibilizadas online, de forma a contribuir com a formação de professores no contexto do pensamento computacional.

Palavras-chave: Pensamento Computacional; Inteligência Artificial; Formação Continuada de Professores; Escola Básica

INTRODUCTION

According to UNESCO (2019), the development of artificial intelligence (AI) must be controlled by humans and centered on people – and must be at the service of society to improve human capabilities.

Considering the universe of possible applications, Artificial Intelligence can acquire a role of great impact in the field of Education, if used to support the teaching and learning process.

Kaufman (2018) argues that:

> Transforming the education system is a slow process, and the content of new skills is not clear. A Deloitte study indicates that 65% of children who entered primary school in 2016 will

> perform roles that do not exist today when they become economically active (in 15 years). In parallel, and equally relevant: professionals with preserved functions need to be "trained" to interact with AI, that is, to adapt to the shared work of man-intelligent machines. (n/a).

The 14th Edition of the Horizon Report (2016) identifies and describes emerging technologies that may have an impact on learning, teaching and creative inquiry in education – and some trends, challenges, and developments within educational technology, considering their impacts on education.

The authors of the report highlight the lack of knowledge about the modes of operation and the impacts of computational means on society and culture, and hope that the data made available by their research will help to support teaching, learning and creative inquiry, in particular, higher education.

There are two sides of the coin in this context – because, while AI may have an impact on a school's activities, the proposals of educational systems curricula do little to prepare students for involvement in this topic. Currently, AI professionals' training most likely begins in adulthood.

In Brazil, the Common National Curriculum Base (BNCC, Brazil, 2018) indicates the presence of AI in high school curricula by means of educational or integrated itineraries, indicating the ability (EM13MAT405) – "Use initial concepts of a programming language in the implementation of algorithms written in common language and/or mathematics." (Brazil, 2018, pp. 539 and 544).

To elementary schools, the BNCC (2018) indicates certain skills as part of thematic units, as follows:

> Another aspect to be considered is that learning Algebra, as well as topics involving Numbers, Geometry and Probability and Statistics, can contribute to the development of students' computational thinking, considering that they need to be able to translate a given situation into other languages, such as transforming problem situations, presented in the mother tongue, into formulas, tables, and graphs, and vice versa. Along with computational thinking, it is worth highlighting the importance of algorithms and their flowcharts, which can be objects of study in Mathematics classes. An algorithm is a finite sequence of procedures that allows a given problem to be solved. Thus, the algorithm is the decomposition of a complex

> procedure into its simplest parts, relating and ordering them, and can be graphically represented by a flowchart. Algorithmic language has points in common with algebraic language, especially in relation to the concept of variables. Another algebra-related skill that is closely related to computational thinking is the identification of patterns to establish generalizations, properties, and algorithms. (p. 273).

However, Berrocoso, Sánchez and Arroyo (2015) proved in 2015 that educational systems are incorporating new official curricula with related topics and discuss two curriculum projects – in the United Kingdom and in the Autonomous Community of Madrid – which had already included algorithms into the early years of elementary school.

How can this picture be changed in our context so that, in the early years of elementary school, some basic computational thinking knowledge may be introduced and have a more positive impact on the training of these professionals? What is the support of Education in elementary schools that is capable of supporting AI professionals of the future?

We believe that this picture can be changed through adequate training of basic education and elementary school teachers, so that they may get involved in teaching and learning algorithms – and so that their students start developing computational thinking in the early years of school life. These ideas are considered in the Programaê! (2018) guidebook:

> If we understand computational thinking as a deep and systematic process that requires mastering several skills to effectively use information, adding steps that include abstraction, decomposition, pattern recognition and – why not? – algorithms, we will find the relationship of this idea not only with the challenges of man reaching space, but also with those inherent to creating and innovating in today's society! (p. 13).

This is the proposal of this project: to offer training for elementary school teachers, so that they can work with their students in teaching and learning algorithms, as already indicated by the BNCC (Brazil, 2018, pp. 273), contributing to the development of computational thinking.

The term computational thinking offers a new approach in the field of cognitive science, based on the premise that the inclusion of Computer Science concepts in basic education can develop a different abstraction skill, which helps children to solve problems in all fields of life, not just in the use of computers or for future computer scientists. Computational thinking, as a cognitive process, systematizes the steps of problem solving, the algorithm, which can be applied to other sciences.

Tori highlights in the Programaê! guidebook that:

> Computational thinking, the basis for any current profession related to the development, implementation and management of technology and computer systems, will be incorporated into almost all professional activities in the future. More than that, the elements present in this way of thinking (such as logical organization of information, abstraction of problems, breaking complex problems into orchestrated sets of simpler problems, and sequencing of steps to solve them) can also be very useful for activities of daily life, use of digital products and services, interaction with professionals from different fields and even as a means of learning, during and after basic education. (p. 9).

The computational thinking context was first approached by Wing (2006) to address Computer Science and its applications. According to the author, computational thinking involves everything from the structuring of reasoning to human behavior for problem solving, and can be observed in the processes of reading, writing and mathematics as an integral part of the analytical ability of children from an infant age (Wing, 2006). The author Paz (2017) argues that computational thinking as well as reading, writing and arithmetic must be added to the analytical capacity of every child.

> There is talk of teaching computational thinking to students, and why not do the same for teachers? To teach them how to find the processes involved in the formulation of real problems and their solutions (computational or not), so that they can be performed by any information processing agent, either human or machine (Wing, 2010). Knowing how to use the computational resources made available by ICTs also requires the competence of computational thinking. (p.1660).

Thus, the project proposes to offer basic school teachers, preferably from public schools, training in the context of computational thinking – and to assess the impact of these teachers' understanding on their respective concepts and practices. The introduction of computational thinking in training courses is expected to effectively influence teachers' understanding of the subject, and to have a positive impact on their teaching practice.

HISTORICAL SUPPORT

Issues related to the teaching of mathematics have been problematized since the beginning of the 20th century. In England, at the beginning of the second decade of the 20th century, John Perry indicated that "the method of study called Practical Mathematics is that the student should become familiar with things before he is asked to reason about them" (Perry, 1913, p. 21). In France, Emile Borel (1904) proposed the creation of the so-called "*atelier mathématiques*". In Germany, Felix Klein (1849-1925) proposed the use of concrete models and dynamic instruments – and, in Italy, the idea of mathematics laboratories in schools was presented by Giuseppe Vailati (1863-1909). All this happened long before the beginning of the epic revolution triggered by the work of Alan Turing, pioneer in the development of computer science, of formalizing the concept of algorithm, and of driving computing by means of the Turing machine. Turing's work and role throughout history made it evident that the development capacity of nations is related to the level of mathematical knowledge of their citizens, as well as to their ability to apply it in various fields, namely in computing and innovation.

From the moment computers became part of the daily life of institutions, the works of Seymour Aubrey Papert (1928-2016) emerged – pioneering in the use of computers in the teaching of mathematics; creating the Logo software at the Massachusetts Institute of Technology (MIT); and developing research and theory regarding the use of computers in education.

In his first report to the Artificial Intelligence Laboratory, Papert (1971) pointed out three general principles for the role of computers in education; here we quote the first one, that contains a strong metaphor, recalling the recent commemorations of the 500th anniversary of Fernando Magalhães' circumnavigation voyage:

> We find that the intention behind this [Mathematical Technologies for Children] is most effectively conveyed by a fantasy. One might dream of having children mathematics by giving them a ship to sail the ocean, a sextant to fix their position and, a cargo to trade with distant peoples. A large part of our work is directed at trying to make this dream come true (at least in principle) by creating mathematical instruments, more manageable than Ships and sextants but, which still allow the child to develop and exercise mathematical arts in the course of meaningful, challenging and personally motivated

> projects. In our context the computer is not merely a device for manipulating symbols. It actually controls real, physical processes: motors that turn, trucks that Move; boxes that emit sounds. By programming it, the child is able to produce an endless variety of actions in a completely intelligible, controlled way. New mathematical concepts translate directly into new power for action. Self-generated projects induce an immediate and practical need to understand the mathematics of movements, the physics of moving bodies and the formal structure of sound Patterns (p. 3).

From Papert's work on, investigation and development of experiences in schools with computers in teaching and learning have been numerous over the last three decades of the 20th century; evidence on the positive effect on education, namely in mathematics, has been obtained, as well as the importance of the use of technology in the development of citizens' skills in a world where computers and electronic devices have become part of most everyday tasks.

Valente (2016) argues that:

> The idea that computer programming helps one think better is not new. Since the Logo language was created in the mid-1960s, Papert was already mentioning the importance of this activity to the knowledge construction process and to the development of thought (p. 868).

In the track of Logo, dynamic geometry environments (DGE) began to emerge, now in their third generation. We consider that some of their uses in schools promote algorithmic thinking.

At the beginning of the 21st century, professional mathematics teachers' associations began to recommend demanding application of programs that promote the use of technology for the teaching and learning of mathematics in schools – namely by the National Council of Teachers of Mathematics – NCTM, since 2000 (Martin, 2000); and, even today, the Organization for Economic Cooperation and Development (OECD, 2018), in the context of competences for the 21st century, will begin to consider the use of technology in the Programme for International Student Assessment (PISA) tests to be held in 2021.

In Brazil, there are BNCC indications that can be reflected in the Basic Education Assessment System (SAEB), a set of large-scale external assessments that allows the National Institute of Educational Studies and

Research Anísio Teixeira (INEP) to carry out a diagnosis of basic education and of factors that may interfere with student performance.

We could say that the computer-aided teaching of mathematics (CAM) strategy is a reality in many educational communities, the result of a lot of research and of Papert's initial ideas, made possible by the widespread use of computers and specific software.

In Portugal, in the final report of a document on the subject, (Canavarro et al, 2020) indicate that:

> The Mathematics curriculum, whatever the schooling cycle, must consider technological tools as resources for teaching and learning Mathematics, which favor the adequacy and expansion of the mathematical experience. All students should have free access to calculators, robots, applications available on the Internet and software for statistical treatment, symbolic algebraic calculus, geometry, functions, and modelling. The Internet must be an important source of access to information for teaching and learning Mathematics (p. 296).

Recalling the work of Alan Turing, a pioneer in operationalizing mathematics and logic to the creation of algorithms, the development of the automatic decision-making capacity, the contemporary world now faces a new challenge. Presently, computers are in the palm of the hands of many students; these devices increasingly use AI and the key question is to know how these potentials can be used for the development of peoples and of the common good. Thus, Wolfram Conrad's idea of Computation-Based Mathematics (CBM) is the new challenge (Wolfram, 2020).

Elementary school teachers, in general, have demonstrated, in research carried out by the authors of this project, the need for adequate training to understand what happens in these dynamic devices and how to use them in teaching, revealing a lack of knowledge of aspects of computational thinking to provide pedagogical support for their teaching actions.

UNDERSTANDING THE PROPOSAL

An educational movement has re-emerged in recent years – at international level – concerning the introduction of computational thinking, computer programming and robotics in schools, which had been previously introduced in the 1980s as the first steps of computer science in the classroom, linked to the learning of geometry, using a programming language called "Logo" and its famous "turtle", within an educational project based on the ideas of Dewey, Piaget or Vygotsky, and materialized by Seymour Papert.

Valente (2016) considers that:

> The way in which digital technologies are being worked on in schools, in practically all countries, has not contributed to the development of computational thinking. These activities are restricted to the use of what was called office software, such as word processors and spreadsheets and, therefore, do not explore concepts of Computer Science, allowing the computer to be used as an instrument to think with, and to think about the thinking. This has led some countries to change their Basic Education curriculum (p. 864).

The context of AI in education is suggested by several experts, as argued by author Conrad Wolfram (Wolfram, 2020) – who, believing in the power of computing to make better decisions, considers that there are two sides to achieving this: not only the best computer technology, but also the best education for computational thinking.

For the past 30 years, Conrad Wolfram (Wolfram, 2020) has been a key part of the technological transformation that has brought mathematics, computing and data science to the forefront of today's world and ushered us into the Age of Artificial Intelligence. This gave him unique insight into the widening chasm between school math and real-world math and put him in a crucial position to correct it.

The initiative that is being carried out in Portugal intends to introduce robotics in the classroom as an auxiliary tool in student learning, using robots to support the teaching of different subjects. The tutorial presented in one of Carvalho's texts (2020) emphasizes that the objective:

> [...] is to enable the teacher to take emerging technologies into the classroom, modernizing teaching and providing students with transversal skills (such as creativity, problem solving, communication, among others) that help them prepare for the labor challenges of the future (p. 61).

All these considerations show how AI can be integrated into schools' basic education, but to achieve this goal, we believe it is necessary that these environments have an understanding of computational thinking and of how it can be considered in education from the early years on. To this end, the main actors of the entire process, the teachers, need to be prepared for this mission. Thus, it is important to study how resources that meet this context can be introduced in teaching.

Mathematics teachers have a fundamental role in facing these challenges, since mathematics occupies a common role as language and science in this field and, thus, the scientific knowledge that elementary school teachers of mathematics and sciences need to have, in their practice, is the understanding of computational thinking in the context of AI in the current and future era.

According to Valente (2016):

> Research referring to computational thinking found in literature can be divided into practically three large blocks: the nature of computational thinking and how it can be evaluated (how to identify computational thinking in the learner); the training of educators to carry out activities that explore the concepts of computational thinking, especially integrated into curricular activities; and the implementation, in school, of activities that explore computational thinking and the benefits that these activities produce. Obviously, this classification is of a purely didactic character, since the contents of these three blocks are closely related. (p. 867).

Valente (2016) also considers that: “The training of teachers that would enable them to carry out activities referring to computational thinking has occurred both in the context of initial and continuing education” (Valente, 2016, p. 886), and offers examples of others countries that can be considered an inspiration for our proposal.

Also inspiring is the European MoMaTrE, a project that combines traditional math trails and new technologies by means of a web portal and mobile app (MathCityMath-MCM), guiding users along a math trail with different tasks, giving feedback on user responses, and hints if they get stuck on an issue.

This example is a context ready for exploring what we consider important for education, but in order to build a similar space, we need support for elementary school teachers, by means of collaboration and reflection on the development of computational thinking through work modules to be developed.

In Brazil, some research was carried out in the context of teaching practices (Siqueira, 2012; Ramos, 2014; Couto, 2017; Silva, Silva & França, 2017), which were the initial steps for the development of computational thinking in schools.

In this sense, the objective is to work on an approach that could engage teachers in practical activities that mix different knowledge and lead to creative learning through algorithms and other aspects of computational thinking.

METHODOLOGY[1]

In developing this qualitative, longitudinal, and sequential project, it is absolutely necessary to describe the phenomena of educational interaction in order to problematize and understand, as a whole, the dynamics of the process established during learning and teaching, in the context of computational thinking, and from an interdisciplinary perspective.

At the same time, the methodology seeks to analyze the results obtained by studying the continuum of learning over a significant period, generally referred to as follow up, considered increasingly relevant since it allows following the track and removing inferences (Bogdan & Biklen, 1994; Stake, 1998).

Thus, from a methodological point of view, observation, the collection of materials produced by teachers, and document analysis are all data collection instruments used in this study. We intend, in this way, to describe, problematize and interpret the relationships between the mutually constitutive elements, from the perspectives of the participants involved therein, and from the researchers' own expectations, based on a conceptual, theoretical, and practical field.

This research includes dynamics that are specific to action research, a dynamic track that occurs directly in a natural working environment, with the study participants and their collaboration, especially in the educational field of students and teachers.

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[1] The Free and Informed Consent Form (TCLE) was signed by the participants and the project is under evaluation in the Ethics Committee. The authors are responsible for submitting data, and the journal Acta Scientiae is exempt from any responsibility. According to Resolution No. 510, of April 7, 2016, of the National Health Council of Brazil, full assistance and eventual compensation for any damage resulting from any of the research participants is an authors' attribution.

On the other hand, what characterizes action research is the reflexive spiral made up of four phases that articulate and complement each other recursively: planning, action, observation and reflection (Fernandes, 1992), organized according to three objectives: a) academic investigation, to produce knowledge about reality; b) innovation, which comprises the identification of problems and intervention in order to solve the problems; c) skill development, which consists of developing a process involving all participants, based on the first two objectives.

These are all actions in the context of a Teaching Experiment, a research methodology that emerged in the United States in the 1970s. It is interventional, since it intends to investigate the possibilities of educational improvement, creating forms of learning organization and studying them (Cobb Confrey, Disessa, Lehrer & Schauble, 2003).

The design of the teaching experiment involves creating a sequence of tasks in the context of the project, used as a teaching hypothesis, and subject to reassessments and readjustments (Cobb et al., 2003).

In this investigation, with the obtained and diversified data, we expect to broaden, deepen and, consequently, better understand the subject under study.

WORK DYNAMICS

The authors of this project carry out research and actions in the context of teacher training for the use of digital technologies, in particular with the use of GeoGebra in public schools in Brazil, Portugal and, with the support of the OEI, in some African countries such as Angola, Mozambique and Cape Verde. (Dos Santos, 2019, 2020; Abar, 2020; Abar & Rodrigues, 2020).

Teachers working in public elementary schools were invited by the authors and encouraged to join and participate in the project through the institutions to which they belong. Eleven teachers joined in: one teacher from Angola; two from Cape Verde; five from Portugal; and three from Brazil. They all agreed with the free and informed consent form that was presented to them.

The work dynamic was guided by active and collaborative participation in practical and theoretical activities. The association between practice and theory and the manipulation and analysis of problem situations were all encouraged. In the work sessions, participants were encouraged to deepen their skills in exploring the concepts of computational thinking, in a transversal way, in carrying out activities and in different subjects of the curriculum, in which the following observations were considered.

Lu and Fletcher (2009) indicate that some key points of computational thinking are as follows:

> It is a way of solving problems and designing systems that draws on concepts fundamental to computer science; 2) it means creating and making use of different levels of abstraction, to understand and solve problems more effectively; 3) it means thinking algorithmically and with the ability to apply mathematical concepts to develop more efficient, fair, and secure solutions; and 4) it means understanding the consequences of scale, not only for reasons of efficiency but also for economic and social reasons. (p. 260).

And highlight that:

> CT is not about getting humans to think like computers, but rather about developing the full set of mental tools necessary to effectively use computing to solve complex human problems. (Lu & Fletcher, 2009, p. 260).

In practical activities and in a first phase carried out in the first half of 2021, the tools, commands, and interfaces needed at each moment were addressed. Next, there was work coordinated by the researchers of the project – reflecting, with teachers, on the contexts of computational thinking and the concepts of technologies and algorithms.

In the next phase, from September 2021 on, there will be a discussion concerning the proposed activities, focusing on the conceptual, theoretical, and methodological implications of these tasks, from the point of view of teaching and learning algorithms.

In certain actions, the description-execution-reflection-debugging-new description cycle proposed by Valente (1993, 1999), although not characterized as a "computational thinking" concept, may contribute to explain the proposed activities, and help to understand how the interaction with digital technologies, in some situations, can contribute to the development of computational thinking.

The discussion of the implications of some activities in the field of educational investigation, as well as in mathematical research, was not neglected, highlighting the potential of the resources used in the creation of new scientific knowledge.

The resources created collaboratively will be used in teaching, with their students, and the experiments will be shared in other work meetings for possible improvement and dissemination.

EXPECTED PRODUCTS

In the second phase of project development, we expect to obtain from participants challenging proposals in which computational thinking can serve as a technological mediator in the teaching and learning of Mathematics in the AI era. All obtained products will be made available in a space to be created, and with free access.

For digital transformation in schools, specifically in the classroom, to become a reality, teachers must be prepared to adapt technology to their teaching practices. Teachers need to learn how to use technology in the context of computational thinking, and to decide on the tool that best suits each subject and each class. Thus, we expect that the obtained results may be inspiring for the creation and development of other actions.

THE FIRST PHASE OF THE PROJECT

In an investigation process, Estrela (1990) considers the existence of five essential procedural steps. The first step deals with the collection of structural elements that do not result from direct observation of the investigation. In step two, the dialogue with the institution and the most direct participant in the study is established. In step three, the roles of researchers and teachers and their respective intervention strategies are defined. In step four, guidelines for training participants and data collection are outlined. Finally, in the fifth stage, there is evaluation, in which data are analyzed, and obtained processes and products are problematized and analyzed.

As information is collected and the topic under study becomes better known, purposes, plans, times, and strategies of action are defined (Bogdan & Biklen, 1994). After problematizing the investigation by raising questions, defining objectives, and delimiting the intervention area, intervention strategies were outlined within this structure.

Thus, in each of the five stages proposed by Estrela (1990), intervention actions were included in order to deepen the study as a logical, consistent and coherent whole. In this study, we opted for a qualitative methodology with research action characteristics in the different stages of development planned and referring to teacher education, using as technological resources those who support the development of computational thinking.

In the first half of 2021, six meetings were held between the months of March and July. The first meeting, on March 11, 2021, was held on Zoom (Figure 1); the following invitation was sent:

> *Hi, we hope you are well alongside your family.*
> *Welcome!!*
> *You have accepted our invitation to be part of the group of teacher trainers who will participate in the project COMPUTATIONAL THINKING IN ELEMENTARY SCHOOL IN THE ERA OF ARTIFICIAL INTELLIGENCE: WHERE IS THE TEACHER? by Autor and Autor.*
> *This project will feature partner institutions in Angola, Cape Verde, Portugal, and Brazil. At this first meeting we will meet each other virtually! However, we have also sent you a text with the initial premises of the project, and two reading suggestions, all essential to our first reflection on the project's topic.*
> *Our first meeting will be held on March 11, 2021, at 3:30 PM in São Paulo; 5:30 PM in Cidade da Praia; 6:30 PM in Lisbon; and 7:30 PM in Luanda.*

At first, it was important to find out, in addition to the characteristics of each teacher, the reality of their respective schools, in order to develop a teacher training plan in computational thinking contexts. The opening speech came from the representative of the Organization of Ibero-American States-OEI, emphasizing the importance of projects of this nature in Portuguese-speaking countries. The coordinator from Portugal posed some questions for reflection: How are CT ideas being considered in our local, regional, and national educational communities? Is there any document, whether official or local, that enables support for activities referring to Computational Thinking? How are the discussions about Computational Thinking in each country that participates in the project? Next, the introductory texts on computational thinking – that had been sent in advance – were discussed.

Figure 1

Participants of the 1st Meeting (Teams screenshot)

At the second meeting, on April 8, 2021, also on the Zoom platform, there was a lecture by Professor José Armando Valente in which he presented his understanding of computational thinking and the need for reflection on the respective levels that can guide teacher education in understanding the first steps towards the introduction of computational thinking. He specifically stressed the construction of algorithms, the need for step-by-step description, and the analysis of these procedures. A paper was sent by the professor, in advance, for participants to read: "Computational Thinking, Computational Literacy or Digital Competence? New challenges in education." (Valente, 2019). The professor also stressed the importance of using procedures in the development of activities – and indicated, as an example, the use of GeoGebra with the construction of macro tools, which can be a good instrument for the initial steps of introducing computational thinking through procedures, unlike Scratch, in which commands are used and do not allow for advancement from a computational point of view. It is important that the procedures adopted lead to an understanding of the concepts and practices related to computational thinking.

The May and June meetings, transferred remotely to the Teams platform, were characterized by planning for intervention – that is, after characterizing the contexts, identifying and selecting the training content with resources that favor mathematical learning and development of computational thinking, training modules were prepared; proposals for activities developed in partnerships in synchronous moments were included in these modules.

The invitation was sent by the project coordinator to all participants via Google calendar:

> *I hereby schedule the third meeting of the project. I would like to remind you that, this time, it will be held on the Teams platform, and that the meeting link is below. I would also like to alert colleagues that an invitation was sent to join our working group; pay attention to the links, videos of the sessions that will be useful to us. Attached is the preparation track for our meeting. If you have any questions, please contact me. Have a nice weekend!*

At the meeting held on May 6, 2021, a learning track (Figure 2) was presented to guide the steps to be taken, as well as two texts to complement the ideas proposed in the Ministry of Education and Culture of Brazil's Virtual Learning Environments – AVAMEC platform (2021).

Figure 2

Learning track for the 3rd Meeting (Teams screenshot)

A paper translated by Grover and Pea (2017) was made available, indicating the concepts of computational thinking: Logic and logical thinking; Algorithms and algorithmic thinking; Patterns and pattern recognition; Abstraction and generalization; and Evaluation and Automation, which are all close to those indicated in AVAMEC. In addition, Grover and Pea (2017) point out that computational thinking practices involve the following: Problem decomposition; Creation of computational artifacts; Testing and debugging; and Iterative refinement (incremental development).

We chose an approach that does not require prior knowledge about computing and computers for the beginning of the development of computational thinking available on the AVAMEC platform (Brazil, 2021):

> [..] a collaborative virtual learning environment that allows for the conception, management and development of various types of training actions, such as distance courses, complementing on-site courses, research projects, collaborative projects and various other forms of distance educational support to the teaching-learning process. (n/a)

One of the training actions refers to courses aimed at understanding and using what they consider as pillars of computational thinking and their use in problem solving: Decomposition, Abstraction, Pattern Recognition and Algorithms, in addition to the possibility of Interdisciplinarity and Cooperation. The introductory course, as shown in Figure 3, is made up of modules involving the above-mentioned pillars.

Figure 3

Initial Screen of the Introduction to Computational Thinking course (Avamec)

Grover and Pea (2017), the authors who guided the actions of the proposal, present a synopsis of the chapter, noting that:

> Computational thinking encompasses a range of specific thinking skills for problem solving including abstraction, decomposition, evaluation, pattern recognition, logic and algorithm design. While what exactly is included in computational thinking has been the topic of some debate, this chapter will consider each of the elements of CT, how the learning of these concepts and practices can be facilitated within the school curriculum, and the role of CT skills in other domains (p. 19).

The authors emphasize their understanding of computational thinking, highlighting that:

> Computational thinking is the thought processes involved in formulating a problem and expressing its solution(s) in such a way that a computer – human or machine – can effectively carry out. Informally, computational thinking describes the mental activity in formulating a problem to admit a computational solution. The solution can be carried out by a human or machine. This latter point is important. First, humans compute. Second, people can learn computational thinking without a machine. Also, computational thinking is not just about problem solving, but also about problem formulation (Wing, 2014) (Grover & Pea, 2017, p. 21).

And they also make observations about what computational thinking is not:

> It is easy to fall into the trap that CT is thinking like a computer. Yet it is a trap conveniently avoided if one keeps in mind our framing of 'thinking like a' for thinking competencies. Thinking is an inherently human trait that involves reasoning. Computers do not think, so CT is NOT 'thinking like a computer', rather it is about thinking like a computer scientist. It's the problem-solving approaches commonly used by computer scientists that constitute computational thinking (Grover & Pea, 2017, p. 22).

The above considerations were presented to the participants and, in continuation of the meeting, the course available at AVAMEC (2021) and activities related to the modules of decomposition and abstraction considered, respectively, as a practice and a concept of computational thinking were presented, according to authors Grover and Pea (2017). Such activities, developed synchronously with the participants, were proposed in the form of games, whose answers were requested from participants and inserted in the Teams chat tool. The answers were discussed both from the point of view of the concept of abstraction and the practice of computational thinking involved in the presented proposals.

The practice of decomposition involved in the games was considered a good indication, for example, in the planning of a class that can be created more easily if considered in parts, such as: definition of educational goals; identification of contents; survey of students' prior knowledge; proposal of individual and cooperative activities; definition of the mediation plan; selection of resource materials; study of spaces and times; and planning of learning assessment. Decomposing a problem into more elementary parts allows for making the tasks required to solve a problem more explicit, as well as facilitating communication between the stakeholders involved and the perception of individual and total progress.

Figure 4

Learning Track for the 4th Meeting (Teams screenshot)

In activities concerning the concept of abstraction, considered as the action or effect of selecting aspects of objects or processes that must be considered to satisfy a certain objective, a situation in which a teacher needs to organize teamwork with students can be considered. Which groups can best be structured to ensure the proposal's success? While this may at first appear simple, distributing tasks to members of a group involves identifying task requirements and characteristics (skills, competences, strengths, preferences etc.) of those involved in carrying it out. This need to represent the elements of the considered reality, focusing on the performance of the task by a human agent, is an example of the importance of the concept of abstraction in the planning of activities, especially in cooperatives.

A learning track (Figure 4) was presented during the June 3, 2021 meeting, to guide the steps to be followed, as well as a text to complement the ideas proposed by the MEC platform.

Continuing with the activities indicated in the AVAMEC environment (2021) to identify the concepts and practices in each task, the concepts of algorithms and algorithmic thinking were worked on, as well as patterns and pattern recognition. They were also developed synchronously with the participants and in the form of games, whose answers were requested from participants to be inserted in the Teams chat tool. The answers were discussed from the point of view of the concepts that were being worked on: algorithms and patterns.

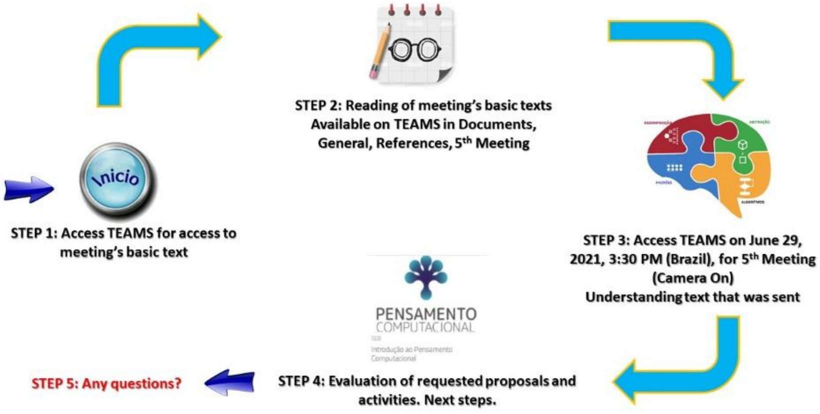
When creating an algorithm, it is important to use techniques that facilitate the construction process; that help us test whether the obtained algorithm solves the problem; and allow us to measure the solution’s performance. The concept of algorithm enables an exchange between knowledge from different disciplines, using a common language to talk about processes, allowing a precise way to specify solutions and integrate the component parts. Algorithms are precise, step-by-step plans or procedures for meeting a final goal or solving a problem; algorithmic thinking is the skill involved in developing an algorithm.

The concept of pattern recognition supports the modeling of decomposed objects, in the search for the identification of known structures in the most diverse disciplines, which can facilitate the exploration of the elements resulting, for example, from decomposition. In pattern recognition, cooperative actions necessarily involve the interaction between group members and the performance of coordinated activities that result from those interactions. There are patterns of interaction, however, that do not contribute to or hinder the work, such as cyclical conversation (no progress), stagnant debate (impasse), and disordered discussion, among many others. Identifying such situations through the resources discussed in pattern recognition is also crucial for cooperation.

On June 29, 2021 the 5th meeting was held as shown in Figure 5. At this meeting, the concepts and practices indicated by authors Grover and Pea (2017) and not developed in the previous meetings – such as logic and computational thinking, evaluation and automation – were objects of study with the participants.

Figure 5

Learning Track for the 5th Meeting (Teams screenshot)



Logical thinking involves analyzing situations to decide or reaching a conclusion about a given situation; and logical reasoning is a process that we can identify and apply to many everyday situations. Any situation that can be studied carefully, making a comparison, and looking for a conclusion or a particular outcome, requires critical analysis. In the scientific field, and in order to define such procedures, Boolean logic, its operators – such as AND, OR, IF, NO – and its logical expressions are used.

As an example, the conditional If (<Condition>, <Then>, <Else>) was presented in GeoGebra software – a command that performs the logical test of an expression. If the test returns a true value, the second part of the command is executed. If the value of <Then> is true, the expression is executed. If it is false, the expression <Else> is executed.

For example, you can get a sequence by typing the following command at Input *Sequence (If(Mod(i, 3)* $\stackrel{?}{=}$ *0, i, 0), i, 1, 20)* and the condition of the *If* command is *Mod(i, 3)* $\stackrel{?}{=}$ *0*. See the command line in Figure 6.

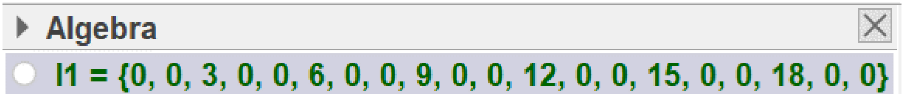
Figure 6

Input Field with the Sequence command (Teams screenshot)

In other words, if, when dividing the value of i that varies from 1 to 20 by 3, the remainder is 0, it returns the value of i, otherwise it returns 0 – thus obtaining the sequence in the algebra window in Figure 7.

Figure 7

Result in Algebra Window of Sequence command (Teams screenshot)



Another concept of computational thinking, evaluation, follows the concepts already presented and according to Grover and Pea: "Solutions to problems in the form of algorithms or abstractions in the form of programs, models or simulations must be evaluated for correctness and appropriateness based on the goal as well as constraints" (Grover & Pea, 2017, pp. 26) When creating an algorithm or analyzing a logical procedure, it is important to carry out ongoing evaluation and review of the process. This invites reflection on the learning process itself and facilitates the development of all skills associated with computational thinking.

Another key piece of computational thinking, automation, is making a machine capable of solving a given problem. Identifying which situations are likely to be processed by a machine and which is the best way to do this job. These are essential ideas for the development of computational thinking. It is important that students are aware of when a process must be automated and executed by a machine, and when a particular problem must be solved by a person. Creating macros in GeoGebra is an example of automation.

Regarding computational artifacts with computational thinking practice, Grover and Pea (2017) point out that:

> Creativity as a CT practice acts on two levels – it aims to encourage out-of-the-box thinking and alternative approaches

> to solving problems; and it aims to encourage the creation of computational artefacts as a form of creative expression. Block-based 'open-ended' introductory programming environments such as Scratch, Alice and App Inventor have been developed with the goal of teaching creative coding and motivating learners as a conduit for teaching CT, especially in K-12 settings (p. 30).

The development of computational thinking is closely linked to the maker culture, which means that enhancing these skills in the educational field does not refer only to coding programs. There are many resources that allow one to create and program simple electronic devices and to introduce educational robotics from an early age without the need, for example, of extensive knowledge of electronics.

And, finally, the practice of testing and debugging to check for results, errors, or modifications is something that can be intrinsic to almost every concept of CT. In any discipline, subject or field, the importance of checking results or looking for errors is emphasized when something is not coherent, so as to improve it. The process of testing, improving, finding bugs, and modifying is a natural part of the problem-solving process. It is closely connected to other concepts and practices mentioned above.

Authors Grover and Pea (2017) reinforce that:

> Like other CT concepts and practices, testing and debugging are related to many of the other elements described here. They are part of the process of evaluating a computational solution – whether it satisfies relevant rules and assumptions, whether the solution works for boundary conditions and all relevant inputs and situations, and whether it acts as expected for illogical or erroneous inputs. This also involves logical and 'if-then' analytical thinking to isolate the problem and zero in on the error. It is also integral to the incremental development and problem decomposition strategies described above (p. 29).

This procedure is very important, in computer science, to develop programs, because it helps find the most ideal way to do a job, evaluate the results and learn to question whether the initial hypotheses established for solving a problem are the most adequate.

Although we expected proposals from the participants during the second phase of project development, some were sent by Teams, and we presented two proposals by Portuguese teachers.

The first proposal, "how to create a compass, with cardinal points in Micro:bit", was developed for 5th grade students, considering the CT practice of decomposition with inherent oriented creation, based on the concept of programming a simple digital compass using a device. In the given guidelines, when students program the various cardinal points, it would be necessary to understand the notion of a circle, the notion of 360º, and to define an interval in which a cardinal point would exist. This activity had as its resource the Micro:bit device (https://makecode.microbit.org/), which allows the use of the simulator inserted in the platform. Using only cardinal points, students had to deconstruct a circle to understand between which angles cardinal points can be considered.

The second proposal, called Collatz Conjecture, proposes a task with the objective of contributing to the development of mathematical skills such as problem solving, mathematical reasoning and the development of a mathematical algorithm aimed at students between the 5th and 10th grades; its difference was in the implementation of the intended algorithm. For 5th grade, the algorithm can be implemented in Scratch (block programming); and, for 10th grade, the algorithm can be presented in the Python programming language. The mathematical conjecture, not yet proven, but whose validity can be verified for natural numbers with millions of digits, considers that, given any natural number, if it is even, its half must be calculated; however, if it is odd, its triple is calculated and added by 1, and so on – and this process will always end at number 1. The resolution of the proposed task should allow the verification of this conjecture by choosing any natural number.

In both proposals, the teachers complemented them with the respective solutions inserted into the aspect of description and debugging of the cycle proposed by Valente (1993, 1999), and characterizing the initial phases of the reflexive spiral (Fernandes, 1992) already presented in this text. The proposals will be discussed in the group at the next meeting of the 2nd phase, in September 2021.

CONCLUSIONS

This paper presented the first phase of the development of a project that proposes to offer teachers training in the context of computational thinking, and to assess the impact of these teachers' understanding on their respective concepts and practices, considered by Grover and Pea (2018).

The first phase of the proposal was carried out with the participation of teachers from Portugal, Cape Verde, Angola, and Brazil, and began in March 2021, with six monthly meetings being held remotely on Zoom and Teams.

Work present in the literature on the subject of computational thinking was presented and discussed, bringing a new approach to the field of cognitive science and its insertion in basic education, as a different abstraction skill that helps children in solving problems in all fields of life, and not only in the use of computers or for future computer scientists.

The involvement of teachers in synchronous meetings was significant, and some activity proposals were conceived, two of them outlined in this paper, as part of the aspect of description and debugging of the cycle proposed by Valente (1993, 1999), and characterizing the initial phases of the reflexive spiral (Fernandes, 1992) already presented in this text. The proposals will be discussed with the participants at the next meeting of the 2nd phase, in September 2021.

With the continuation of the project in the second phase, we hope to obtain other different proposals from the participants, to be published and made available online, in order to contribute to teacher education in the context of computational thinking, thus reflecting on their teaching practice.

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AUTHORS' CONTRIBUTION STATEMENTS

CAAP, JMSS and MVA participated in all phases of project development: preparation, participation in remote meetings, creation of activities, and data collection. All authors actively participated in the discussions and reviewed and approved the final version of this work.

DATA AVAILABILITY STATEMENT

Data supporting the results of this study will be made available by the authors for correspondence, upon reasonable request.

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