Discussing the Challenges Related to Deployment of Computational Thinking in Brazilian Basic Education

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***Abstract*—Computational thinking aims to employ Computer Science foundations to solve problems in different knowledge areas. This paper describes projects related to computational thinking and starts a discussion on the challenges for implementing computational thinking in primary and secondary education in Brazil.**

***Keywords*-Computational thinking; Basic education; Informatics in education; Computer-aided learning; Constructive thinking.**

I. Introduction

The goal of Computational Thinking is to improve several knowledge areas through Computer Science basic elements, supporting complex solution problems using computational concepts [1].

In 2006, Wing described the computational thinking as a fundamental skill for everyone [1]. The idea was supported by multinational companies, such Google and Microsoft, which caused the playing field improvement. This improvement helped the emergence of new project proposals, aiming at promoting the computational thinking propagation in several teaching levels. The Google Inc., in particular, is engaged with this aim, offering a set of activities to assist primary and secondary United States students to learn computation thinking skills [2].

In Brazil, a few proposals have emerged in this direction. Although this theme has already being carried in national papers [3], [4] and the existence of projects proposed by Brazilian Universities [5], [6] aiming at introducing the computation concepts at schools, little progress has been made in educational and governmental fields to effectively implement the computational thinking in Brazillian elementary schools. In this sense, the goal of this paper is to discuss some challenges to be faced in order to implement computational thinking skills in Brazilian primary and secondary educational levels. It consist on a report of a first discussion, started in the context of the project $\mathrm{EXP}^{\mathrm{PC}}$ - *Explorando o Pensamento Computacional para a Qualificação do Ensino Fundamental* [7], developed by professors and students from Federal University of Pelotas.

The paper is organized as follows. Section II presents a brief introduction to computational thinking, containing the history and a survey related to the application of computational thinking in teaching projects. Section III reports the challenges facing the implementation of computational thinking in Brazilian basic education. The Section IV presents some concluding remarks.

II. Computational Thinking

Computational thinking draws on computer science fundamental concepts and involves systematically and efficiently processing information and tasks [8]. Computational thinking can help to solve problems from any study area, and even in everyday life [1]. For example, when you lose something, you can use a technique of *backtracking* to redo the steps to find the lost object. This is computationally thinking on a different level of abstraction [1].

The computational thinking can be defined by a set of cognitive processes involved in the formulation of problems and their solutions, so these solutions are represented in a way that can be effectively performed [1].

The definition of computational thinking encompasses the understanding and solution of problems in a systematic and efficient way [8], exactly the same way that must be designed an algorithm. There are three basic pillars underlying computational thinking: abstraction, automation, and analysis, as described below:

(i) Abstraction, dealing with the ability to extract only the important features of a problem to find its solution, assuming that the others have already been solved. Problems with high complexity degree become difficult to be solved, requiring an appropriate level of abstraction

(ii) Automation, considering the utilization of an electronic device or equipment to replace manual work. A computer is a good example of electronic device that can replace the work of a human being. However, it is not helpful if they are not given the right instructions for performing the desired task.

(iii) Analysis, studying and generating the results. If they do not meet the expectations, it may be because the chosen abstraction level was not adequate, or the automated solution have not been properly designed.

Following, section II-A describes a brief history of computational thinking and section II-B presents the main current projects on computational thinking in education.

A. History

In 2006, Jeannet Wing presented the computational thinking as a way of solving problems, creating systems and understanding human behaviour using the fundamental concepts of computer science [1]. Moreover, the computational thinking is presented as an essential skill for everyone, not just for computer scientists.

Multinational companies like Google and Microsoft supported this idea and are engaged in the dissemination of this methodology. In 2007, Microsoft jointly with Carnegie Mellon University created the Center for Computational Thinking [9]. Google, meanwhile, promotes this methodology across the curriculum of primary and secondary education in the United States [2].

Since then, several programs and projects have emerged to disseminate and implement computational thinking in different educational levels.

B. Computational Thinking in Education

Nowadays, one can see that computation is involved in all areas. For example, in medicine, when doing a surgery using robots; and in economy, with the e-commerce automation, among others [10]. Basics of computing are also present in the people routine. For example, when one cook, there is a parallel processing of tasks: while the vegetables are cut, the water can be heated to cook the food. The pipeline concept can be found, for example, in clothes washing process: washing, drying and ironing.

In 2010, organizations such as Computer Science Teachers Association (CSTA), International Society for Tecnology in Education (ISTE) and National Science Foundation (NSF), have presented a set of tools called *Computational Thinking in K-12 Education – Leadership Toolkit*, proposing a methodology to develop computational thinking skills in primary and secondary education in the U.S. [11].

The toolkit introduces a systematic model of changes for both government and schools, encouraging the creation of new computational thinkers. Additionally, it also proposes a progression framework, which select nine concepts inherent to the computation area as fundamental to be worked at all educational levels. The concepts are: collection, analysis and data representation, problem decomposition, abstraction, algorithms and procedures, automation, simulation and parallelism [11].

Several projects have emerged in order to develop computational thinking skills in different educational levels. Among them we can mention:

Code Club: is co-founded by Clare Stucliffe and Linda Sandvik in the UK in April 2012, with the proposal to create a programming club in all English primary schools. The project is focused on 9-11 years old children and it proposes to introduce programming by creating games, animations and websites. Several materials and the project documentation can be found in their website for downloading. Moreover, since the project is voluntary, they accept donations [12].

Unplugged Project: is a joint effort of Carnegie Mellon University, University of Canterbury and Google to promote the computation teaching. This project aims to work fundamental concepts of computer science without using a computer. Currently, it offers a online set of features including a book, videos and extra stuff that aims to develop specific computing skills. The book, *Computer Science Unplugged*, available for download in different languages, proposes a set of activities to be used in extension and improvement programs, or even in regular classes. They accepts new members to complement the content [13].

Growing Up Thinking Scientifically (GUTS): is an extra-curricular summer project that encourages students to practice scientific inquiry through investigation of issues relevant to the community, planning and implementing real-world problems. The project is developed at the Santa Fe Institute, New Mexico, and it is focused on students of primary and secondary school levels [14].

Computational Thinking: is the project that aims to prepare students of Teacher Licensure Programs in Computer Science to teach the foundations of computing to elementary school students. Another goal of this project is to introduce the computation to the local community, encouraging them to get and know the university campus, courses, teachers and other students. The project development is being done at the Federal University of Paraíba, Brazil [5].

Scalable Game Design (SGD): is a project developed at the University of Colorado at Boulder, aiming to integrate Computer Science into schools, creating games to introduce computing concepts through the *Scalable Game Design*. One goal of this project is allow students and teachers to quickly start with the development of games, rising from simple games to sophisticated projects over the time. The project has reached the milestone of 1,200 students instructed in three years [15].

Scalable Game Design Brazil (SGD-Br): is a research project on teaching and learning of computational

reasoning associated with *Scalable Game Design*. Its goal is to develop the Brazilian technology in order to stimulate and support the computing in elementary and middle schools. The PoliFacets is an example of a tool developed in the scope of this project, which allows interaction between games projects and simulations. The SGD-Br is developed by the Pontifical Catholic University of Rio de Janeiro (PUC-Rio), Fluminense Federal University (UFF), Semiotic Engineering Research Group (SERG) and Laboratory of Active and Intelligent Design Documentation (ADDlabs) [6].

III. Challenges

It is plausible the idea that computational thinking can be present in several areas of knowledge. However, the main research challenger seems to find a satisfactory way of exploring their concepts and introduce them into the curriculum of Brazilian basic education

Considering the computational thinking as a methodology that can bring benefits for the Brazilian students formation, we will address below some issues and the main challenges to be faced in its implementation in Brazil. From our point-of-view, these requirements are: improve the infrastructure of public schools; rearrange the curriculum; prepare the professionals; and, publicize this methodology for the general community.

A. Infrastructure of Educational Institutions

There are a considerable percentage of Brazilian public schools with poor conditions of infrastructure [16]. For a school to be considered as basic infrastructure it should have at least: boardroom, electronic equipment like TV, DVD, computer and printer for administrative use only [16]. Therefore, a computer lab, room for teachers, library and a schoolyard for outdoor practices are not basic requirements to the infrastructure of a school [17]. Due to aspects such as the scale of the problem (Brazil has continental dimensions), the investment capacity of governments and the current distribution of resources for education, we can conclude that the policy currently adopted is not sufficient to solve the infrastructure problems of the public schools.

These issues are an impediment to include the computational thinking in basic education. The development of specific skills depends on activities that require the use of computers. So, the schools must have at least one computer lab (ideally with one computer per student in the class) in good conditions. Since actually, many schools have computer labs in deficient conditions. Moreover, incompetent management dealing with public money is frequently observed. We can easily find schools having new computer labs, which have not been installed [16].

B. Rearrangement of the Curriculum in the Educational Institutions

Our work proposes two ways to rearrange the curriculum to facilitate the introduction of computational thinking in the Brazilian basic education.

In the former strategy Computational Thinking is introduced as a new subject, presenting main concepts properly for each grade and developing the specific skills related to computer science. But, the planned workload may be fulfilled by regular subjects, and to reduce few hours in a particular subjects would affect the achievement of its previous plan. Before implemented, this proposal would have to be carefully studied, eventually restructuring the subjects already provided in the curriculum or even introducing specific workload.

The latter way is to incorporate computational thinking into existing subjects. This would cause a change in lesson plan of traditional subjects, leading to the programmatic content reorganization in order to include the computational thinking fundamentals. Moreover, this proposal requires specific training of the teachers in order to teach the main concepts of computational thinking and create new activities in the context of their subjects [18].

These proposals should be studied in a multidisciplinary way by the government, researchers and professionals, from education to computing, in order to have a comprehensive and adequate inclusion of Computational Thinking to the Brazilian reality.

Currently, the curriculum of Brazilian basic education is considered very flexible because it can be defined respecting local and regional characteristics. However, this does not constitute a homogeneous curriculum model, which overlaps with political and executive powers of the states and cities and the sociocultural diversity of the different regions of the country. Therefore, it is plausible that computational thinking can be added to the traditional curriculum, with the aim of transforming the educational reality by government authorities, schools and teachers.

C. Qualification of Professionals in Educational Institutions

Another aspect to be addressed is to determine what is the appropriate background of the instructors responsible for teaching the concepts of computational thinking.

One the one hand, we believe that would be more appropriated that professionals graduated in BSc in Computing took the responsibility for the implementation of computational thinking in basic education. One the other hand, we also consider that the preparation of elementary education teachers in basic concepts of computing can provide them an additional methodological resource, which would help them in their classes, and would also help in the dissemination of the computational thinking.

A first step consists in organizing events for the dissemination of the methodology and for professional qualification, directed to state- and federal- level leaders, education leaders, teacher educators or general community.

If we choose to prepare elementary education teachers, graduates in computing should organize and manage training courses, addressing the fundamentals of computer science focused on elementary school. Subsequently, a careful evaluation process that measures if the acquired expertise is enough to disseminate the developed concepts in elementary school should be performed.

An alternative suggestion would be the joint work of graduates in computing and teachers of elementary, primary and secondary education. Lesson plans would be drawn up with activities that introduce the concepts of a particular subject and, at the same time, that develop specific skills of computational thinking. This alternative would not significantly change the load-time already provided to the course.

Another important aspect is the need for adequate teaching materials. Textbooks dealing with concepts and proposals for the development of computational thinking in basic education are (almost) non-existent in Portuguese. The increase of professionals graduated in BSc in Computing would promote the development of didactic books. The integrated knowledge in computing and education could adequate the professionals to meet this demand. The implementation of computational thinking in basic education will be successful only if, in addition to qualified professionals, we also would have qualified material available.

As a next step, open and distance learning courses can be an alternative for disseminate fundamental concepts of computing to the school community. However, it should be taken in account that the necessary infrastructure in schools should be available to students for remote access of the material.

D. Dissemination of Computational Thinking

The planning and development of strategies to disseminate the benefits of computational thinking in the education of all students is a first step to be achieved.

Computer scientists should provide an effective channel for disseminating the main benefits of this methodology to politicians and educational leaders. Then, a plan for systemic change should be proposed, including workshops for disseminate the methodology for teachers of basic education, projects for the development of appropriate textbooks, proposals for a curricular change and events for the dissemination of computational thinking to the wider community.

Based on the discussion above, an additional suggestion is to implement more BSc in Computing courses at the undergraduate level in Brazil. Undoubtedly, the professional qualification must go along with the proposal of a curricular reformulation of basic education in Brazil.

Finally, after a detailed and concrete proposal of the development of computational thinking to the various levels of education, its implementation should be taken to the classrooms.

IV. Conclusion

Since 2006 computational thinking is pointed as a set of habits, cognitive skills and fundamental approaches to problem solving through the use of computers, and are widely applicable in the information society [8]. This skill set is for all areas, not only for computation [1].

Companies like Microsoft and Google are committed to promoting computational thinking, either with funding centers as the Center for Computational Thinking in the University of Carnegie Mellon [9], or with the development of on-line repositories to support student learning [2].

This article aims to motivate a broader discussion about the deployment of computational thinking to the Brazilian community. Possible task forces were discussed in order to explore computational thinking in basic education.

In this context, many challenges must be overcome: the infrastructure in schools should be improved, a curricular reformulation should be addressed, teachers must be trained and qualified and everyone must be exposed to this skill.

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