Computational Thinking: Panorama of the Americas

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***Abstract*— Computers cause an impact in almost every single aspect of our lives, however, unfortunately, schools have not been able to keep up with this irreversible evolution. The simple use of technological apparatuses in the classroom does not guarantee the improvement of the learning process, however it can be the medium through which the students find the alternatives for the solution of complex problems. The Computational Thinking is an approach of teaching that uses a diverse range of techniques derived from computers for the resolution of these problems combined with the new competencies of the 21st century (critical thinking, collaboration, etc.). The adoption of the notion of Computing within the basic education schools is a concern in many countries, where the implementation occurs in a strict way. Admittedly, it grows the idea that the Computing discipline is very distinct from the computer classes and that the use of skills from Computing possesses educational (reflection and problem solving, the comprehension that the world is ingrained with the digital technology) and economic (high demand of professionals with good training) benefits. This article, through the vast bibliographic review, describes an international landscape of countries of all Americas, in order to contextualize the reader in respect to the adoption of Computational Thinking within the basic education schools.**

***Index Terms*— Computational Thinking, Basic Education, Computing at Schools.**

I. Introduction

We live in times marked by the fluidity of the information and the valorization of knowledge. More than ever, to deal with the information, process it and transform it in competencies for live, requires, at first, the domain of a series of tools and technological resources, whose access should be possible to everyone, without any distinction of any nature.

Whilst enthusiasts are increasingly excited due to the speedy fashion with which the technology advances, allowing even the computer itself becomes more "intelligent" than a human being, many critics receive this prospection with terror. In the current times, the challenge that is imposed to users is the one which is to create their own systems (E.g. programs, games) or modify the existing ones according to their own necessity. It is in this context that arises the aptitude that is seen as crucial in the 21st century: The Computational Thinking (CT) [1]. Wing defines the CT as a mental activity for the formulation of a problem that is possible to be solved computationally, that is, these are the thinking processes involved in the formulation of a problem and that express their solution effectively, in such a way that a machine or a person can perform.

The Computational Thinking utilizes four techniques (also known as pillars) to achieve the main goal of this approach: problem solving. All four pillars have great relevance and are independent during the process of formulation of solutions computationally viable (see Fig. 1). The CT involves identify a complex problem and break it down in smaller pieces and easier to manage (Decomposition pillar). Each one of these smaller problems can be analyzed individually with greater depth, identifying similar problems which were previously solved (pattern recognition pillar), focusing only on the details that are important, whilst irrelevant information is ignored (abstraction pillar). At last, steps or simple rules can be created to solve each one of the sub-problems found (algorithms pillar). Following the steps or rules used to create a code, it is also possible to be comprehended by computational systems and, consequently, utilized on the resolution of complex problems, efficiently [2], regardless of the area the student intends to work in the future.

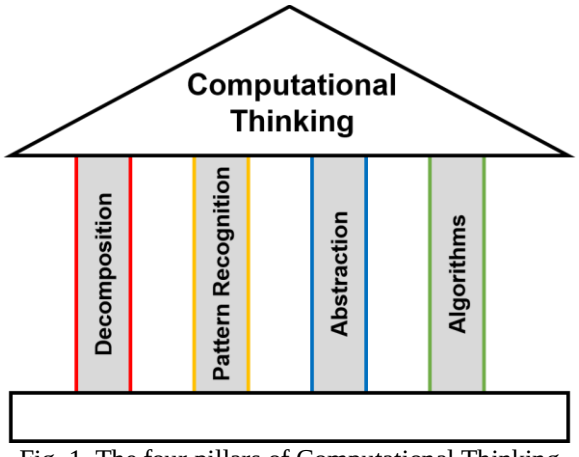

Fig. 1. The four pillars of Computational Thinking

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The adoption of computing notions at basic education schools is a concern in various countries, where the implementation occurs in a format of new disciplines in the school program or in the form of multi, inter or transdisciplinary. Admittedly, it grows the idea that the computing discipline is quite distinct from the computer classes and that the use of skills from computing possesses educational (reflection and problem solving, the comprehension that the world is ingrained with the digital technology) and economic (high demand of professionals with good training) benefits. The Computational Thinking, in addition to being beneficial to the society, is seen by certain countries as strategic for its development and open ways to achieve new markets.

This article is divided in four chapters. The first aimed to introduce the Computational Thinking to the reader, then, is presented a panorama of the adoption of CT in schools in the Americas. In the third chapter are reported initiatives of non-governmental institutions and finally, are presented the conclusions and future work.

II. INTERNATIONAL PANORAMA IN THE AMERICAS

In research led by Microsoft, [3], was conducted a survey of international scope in order to investigate the situation of the introduction of disciplines focused on teaching how a computational system works (do not confuse with the simple use of software). Unfortunately, it is not possible to do a homogeneous comparison between the countries, because the educational systems differ a lot among themselves.

Other aspects of digital technology are important in the education, including basic digital literacy) the ability to use the computer and the internet reliably) and the application of technology as a support to other disciplines or areas.

A. Argentina

Released in January 2013, the Sadosky Foundation published a manifest denominated "CC-2016: A proposal to refound the teaching of computing in Argentinians schools" [4], that has as a main goal to build awareness within the scientific community regarding the importance of a deep change in the teaching at secondary and high school levels, with the introduction of computing principles in its structure. The document argues that the teaching of computing is essential for major opportunities provided by these technologies. Besides that, the organization warns the necessity of the students to develop essential skills for the modern life.

In August 12th, 2015, was released a resolution number 263/15 [5] by the Argentine Federal Council of Education, moved by the strategic necessity of socio-economic development of the nation, establishing various elements, amongst them:

- Teaching of programming as part of the program or as an activity extra-class in schools during the compulsory years;
- Creation of the "Chain of schools the program" (REP), categorized according to the availability of teachers with formation and provision of classes;
- Intensify the propagation of the REP in all jurisdictions covered by the Education Ministry to reach the State educational institutions, through specific initiatives of docent training and during the work;
- Creation of the annual prize "Clementina" for the outstanding productions in the computing field and developed by the students from the schools that are a part of the REP;
- Creation of the national repository of computing production, making the process open to the other members of the REP (schools, faculty and students).

The document was approved, having as a foundation the resolutions 123/10, which deals with the policies of digital educational inclusion, 244/15 where are also approved intensifications in the use of TICs at schools for the improvement in the process of teaching and learning and the article 3o. From the National Educational Law.

B. Chile

The introduction of technological digital resources in the secondary and high school levels began over twenty years, culminating in the creation of the test SIMCE-TIC (Measurement system of education's quality) which is applied since 2011.

According to the report "The Global Information Technology Report 2014", published by the World Economic Forum [6], Chile leads the usage of Information, Communications Technology (ICT) ranking in Latin America (position 35 in a global level) and according to the Interamericano Bank of development, also possess one of the best school infrastructure in Latin America. Even with these initiatives, Chilean students are distant from the access of computing concepts at schools, especially, the youngsters who are in vulnerable contexts, where they have less access to technology.

According to researchers from Chile University [7], the teaching of Computational Thinking at schools would impact positively the country's intentions to become developed through an ambitious action plan: introduce the Computational Thinking in the medium term on the basic education program. This proposal requires great effort, being more evident the training of new members of faculty and training of the existing members of the faculty, through partnerships with schools, parents and, public and private companies, higher education institutions and the Government.

C. United States of America

Signed on the 10th of December of 2015, the Federal Law "Every Student Succeeds Act" (ESSA), is responsible for the public policies in this country. In this document, are being detailed, since the way how the funds occurs, to the way the schools are reviewed.

This law also places the Computing in equal conditions with other academic disciplines, such as Mathematics, Geography, History, English and Science. The document does not define how the implementation should occur, however, encourages its adoption and allows the acquisition of resources for that matter (State and Federal scope). Even after

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the signature of the law, according to Code.Org [2] and Guzdiall [8], the country still does not have a specific legislation for the teaching of computing as mandatory, however, there are state initiatives that allow to make the formal teaching a reality, replacing disciplines of Mathematics, Science, Foreign languages and others, by Computing. Until early 2016, 54% of the schools in the United States have already adopted this discipline's equivalence.

The participating States follow the program proposed by the Computer Science Teacher Association (CSTA) denominated "A Model Curriculum for K-12 Computer Science" [9], where realizes properly structured counseling, within the computing teaching at the schools, since kindergarten up to the last year of high school, in addition to exemplifying exercises that can be carried out in class.

The country had great impact in respect to the comprehension about the Computing Science from the launching of the project Code.Org [2], attracting the attention of students, parents and schools. In recent research ordered by Google and executed by the company Gallup [10], amongst various data collected, stand out in this work:

1) 90% of parents want that their children have Computing classes at school;

2) 50% of parents believe that Computing Science is, intellectually, as important as, reading, writing and calculation.

Currently, the bill presented in the senate and congress by Casey [11] e Brooks [12], respectively, was not enacted to this date. In the year of 2015, the Senator Casey submitted a new appreciation request and since April is waiting for continuity.

D. Brazil

In Brazil, by the time of the elaboration of this document, the technology-related educational policies are restricted to literacy and digital inclusion approach. No official document mentions basic Computing teaching.

In 2015 began the National Common Program Bases (Base Nacional Curricular Comum - BNCC), defining the essential knowledge, to which all Brazilian students have the right to accession, as well as appropriating it during the basic education [13]. In the process of renewal and improvement of the basic education in Brazil through the BNCC, the Brazilian Society of Computing (Sociedade Brasileira de Computação - SBC) is actively engaged in the introduction of Computational Thinking in this major national project of great repercussion, through actions with the others societies and institutes, with the intent of joining forces, proposing new guidelines for the alignment of the programs of the degree in computing and of BNCC and also the creation of promotion and awareness building material.

SBC wrote a document with various arguments, proposing the inclusion of CT as part of the new program to Ministry of Education (Ministério da Educação - MEC), however, until this moment, there has not been an answer from the government.

The initial version of BNCC does not make any reference to an area of Computing, but presents digital technologies as an integrating theme. Within this theme, the languages area is the one that possesses more references, because it has an area in Portuguese called Cultural Practices of Information Technology and Communication. That is, it is not yet recognized in Brazil the importance given to the knowledge linked to Computing, in a way that it is in other countries. In this sense, the Brazilian Society of Computing (SBC) organized itself to request changes in the content of BNCC, aiming to consider computing as an area of knowledge [14].

There are also efforts from SBC in order to disseminate the Computational Thinking in the basic education in Brazil. One example is the Computing Olympics in Brazil (Olimpíada Brasileira de Informática - OBI), that is, "a competition organized using the same format as other scientific olympics in Brazil, such as Mathematics, Physics and Astronomy. OBI's goal is to arouse students interest for an important science for the basic training nowadays (in this case, Computing Science), through an activity that involves challenges, inventiveness and a healthy dose of competition" (olimpiada.ic.unicamp.br).

On the other hand, a solid body of researches and projects, involving the teaching of Computing in the basic education, is realized in Brazil since the 80's. These initiatives are many and diversified. Around 1980's decade, Papert [15] begins the usage of the LOGO language at schools around the world. In Brazil, until the year of 1996, many projects were executed with this type of programing language [16]. The usage of educational robotics, which started with kits of companies such as Lego, nowadays is largely disseminated in many schools and educational institutions, using, as a matter of fact, low cost alternatives, involving sometimes the recycling of electronics components.

Several initiatives of introduction to the Computational Thinking has been executed over the last years, involving researchers from schools and universities, in various levels of schooling [17] [18] [19] [20].

The theme of Computational Thinking has also become the focus of many master's and doctoral work, whose results are normally disclosed in conferences as the Workshop of Education in Computing (WEI), during the Annual Congress of the Brazilian Society of Computing (CSBC) and the Brazilian Congress of Computing in the Education (CBIE).

Other initiatives worthwhile mentioning are the Code clubs, organized by volunteers to bring programing to the schools, the creation of environments of programing in Portuguese such as Portugol [21] and initiatives that incentivizes teaching programing in large scale such as Programaê, which has reached more adepts every day.

III. PRIVATE AND NON-GOVERNMENTAL INITIATIVES

Where there is a high demand of professionals with the proper training in the market, however does not exist an enough flow in the educational institutions, various private and non-governmental initiatives emerge with the intent of assisting this demand. Some examples of these initiatives are presented in this chapter.

A. *Code.Org (USA)*

Launched in 2013 in the United States of America, the Code.Org is a nonprofit organization dedicated to the expansion of the access to Computing Science, including minorities. It has, as a vision, provide students with access to Computing Science, in addition to incentivizing them towards the importance of this discipline in the school program, along with the others, such as Biology, Chemistry and Algebra. Code.Org has as main objectives:

- Increase the cultural and genre diversity in the Computing Science (CS);
- Inspire students;
- Create courses focused on the CS;
- Bring the CS to the classroom;
- Train teachers;
- Alter the program in scholar districts;
- Assist / suggest on the change of State laws for the inclusion of CS on the program;
- Enable students from all over the world to have access to this material.

The NGO (Non-Governmental Organization) Code.Org has had a great acceptance in the US, attracting the attention of major companies in the IT (Information Technology) area, receiving great support of these companies in favor of the promotion of their purposes. Some of the partner companies are: Amazon, America Airlines, Apple, Association for Computer Machinery (ACM), Computer Science Teachers Association (CSTA), Disney, Dropbox, Facebook, GitHub, Google, Khan Academy, Microsoft, Rovio, Salesforce, Zendesk, among others.

One of the most important initiatives of Code.Org is the "Hour of Code". The Hour of Code is a global movement which reaches tens of millions of students in more than 180 countries. Any person, regardless of the location can organize this event. Tutorials of one hour of duration are available in more than 40 languages. It is not required any experience from the participants. People between the age of 4 and 104 can take part of it. In 2015, 191.035 events were registered all over the world. Until the year of 2015 the initiative has reached more than 147.900.897 participants overall.

The main goal of this campaign is that this tens of millions of students mentioned take part in the Hour of Code during the period pre-established by the NGO. In 2015, between 7th and 13th of December, was celebrated the Week of Computing Science Education. The Week is organized with focus on the promotion of the event, however, the activities are available permanently at the website. In Brazil, the main partner of Code.org is Programae.org.br.

B. *Programae (Brazil)*

It is a Brazilian initiative founded in 2002 by the businessman Jorge Paulo Lemann, the Lemann foundation is a nonprofit family organization, promoter of this initiative. Lemann foundation develops and supports innovative projects in education, by the execution of research to lay the foundation for public policies in this sector offering training for professionals of the education field and improving leadership in several areas. The initiatives and actions seek to contribute for Brazil to present, until 2018, innovative solutions of high quality, in the everyday of education of 30 million people, in the training of 200 thousand teachers, in order to ensure the learning of all their students and, yet, 65 leaders promoting and accelerating high impact social actions, in addition to a decent standard and high expectations of what is expected in the education and learning of all students.

Programae.org.br is a partner movement of Code.Org and has as a priority to approximate the programing to the daily life of students all over Brazil and was created due to the high transformational power of technology. According to the NGO, using it for the education can make a difference to many people, through a practical and ideas aggregator portal, solutions and tips from inspiring and experienced people.

C. *Supergeeks.com.br (Brasil)*

It was the first programing school and robotics for kids from 7 years old and teenagers in Brazil. The classes are based on games creation, applications, robotic systems, entrepreneurship and the English language. The idea of setting up this school came to light during the period that a Brazilian couple lived in the US, more specifically, in Silicon Valley, where it was noticed that companies and american politicians were mobilizing themselves to teach Computing Science to kids and teenagers. Today, SuperGeeks is expanding itself all over Brazil through franchises and own branches. In 2016 there has been the opening of one more school in Porto Alegre, at Rio Grande do Sul's State, adding up to 31 schools in Brazil. SuperGeeks uses four teaching methodologies, which are:

- Game learning: Usage of games to promote learning of programing concepts and Computing Science. Some of these games are owned by the school, others are commercially available titles.
- Gamification: usage of games mechanisms as points, prizes and challenges in a ludic way to engage the students to the learning process. The students receive or lose points as if they were in a game. In each task performed, points, lives or credits are earned. If a student does not deliver a given task or show an uneasiness attitude or even indiscipline during the classes, loses punctuation or lives, that is, uses the same game mechanisms inside the classroom, during the course;
- Entrepreneurship: Since the first stage, the students learned about the games industry, how to project them the best way, which are the best distribution channels and advertising. From the stage 3, the students will be encouraged to create their own startups, alone or as a group and launch their products in the market; be it a game, an application, a web application, a hardware or any other type of technological product. As the stages progress, the students will have contact with the marketing concepts, sales, law, accounting, MVP (Minimum Viable Product), Canvas, among other concepts extremely important for entrepreneurs and future business man.
- Storytelling: Stories inserted in animations, books and comics for students to absorb this content in a more pleasant

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way. The adventure stories are being inserted in the content. Thus, in addition to student learning in class or studying the apostille at home, he or she will review the content by reading, watching or listening to these stories.

D. Developing the Computational Thinking (Chile)

Initiative of the department of Computing Science of Chile University, seeks to approximate the computing to students within the scholar age group (between 8 and 12 years of age). The initiative consists of a 'Scratch' workshop, to teach how to create animations and games in a fun and interactive way and so that they can exploit according to personal tastes and skills [22].

The project began in 2002, where occurred the first workshop, which consisted of two shifts during the school period, however, due to the interest of students and partnerships with other institutions, the workshops were also offered during the school holidays. Currently, the course has a new format and takes five days, three daily hours during the morning and also activities from Computing Science Unplugged, besides the Scratch.

The group that coordinates the workshops intends to create a network of Computing Thinking, in the future, linked to basic education schools and higher education institutions in order to integrate the teaching of Computational Thinking effectively in schools in Chile.

IV. CONCLUSION

Currently, we see great support and interest from several institutions (private and public) in regards to the adoption of Computational Thinking in the basic education. So that people can use the Computing in its full potential, everyone (from kids to adults) should have access to the concepts discussed here, however it is vital to educate the lawmakers and build awareness about the importance of the concepts of Computing, which should be taught since schools. It is also important to make it clear the distinction between IT (physical and logic) and Computing (digital literacy) so that it is not assimilated a misunderstanding of the terms, which is very common to happen.

It is possible to find certain countries going through difficult situations for the adoption of CT in the basic education (teachers without training, insufficient infrastructure, among others). These difficulties are also found in developed countries, such as France, where nine thousand schools still do not have internet access, or, yet, the US, where only 10% of schools have a teacher who could teach Computing classes [8]. Whilst some countries, schools have practically one computer per student (e. G. Australia and New Zealand), others stand out by the quality of education even, sharing one computer to up to four students (e. G. Sweden and Portugal) [6]. A possible way to work the CT, in these cases, is through a disconnected approach, also known as unplugged [23].

There are studies that deal with suggestions for the adoption, however, the most complete is "Computational Thinking Leadership Toolkit" [24], where is presented a sequence of steps to be followed in order to obtain the expected success in the implementation of CT in schools. Among the points addressed, highlights are the minimum skills that students should possess by the end of the basic education, the definition of technical and specific vocabulary and curriculum with levels of learning, actions for the training of teachers, getting teachers involved, parents, society, other educational institutions, industry and authorities, among others. Other guide that perform a deep approach about the necessary steps for the adoption of CT by the schools is from Sadosky Foundation [4].

As future work, it is intended to evaluate in a quantitative and qualitative way the application of unplugged Computational Thinking activities, based on its four pillars, directed to basic education kids (between the ages of 10 and 12) and possible identification of the improvement of the cognitive development of students in order for it to have an impact that reveals the undeniable importance to incorporate the Computational Thinking in the basic education curriculum. In a pilot project and in a small scale based on tests of [25], was possible to identify an improvement on the performance of 12% of students from 5th year of secondary school after only two interventions. In addition, these students had an easier time working with visual programing using blocks (Scratch). In future editions, the tests and interventions will be refined and applied on a larger scale.

This article had the objective to contextualize the work of researchers in respect to the current situation of the Computational Thinking in American Countries, as well as, to educate those entitled the importance in the basic education.

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