Global Education Monitoring Report

Background paper prepared for
the Global Education Monitoring Report

Technology in education

COMPUTER SCIENCE AS A CURRICULUM SUBJECT IN LATIN AMERICA

SADOSKY FOUNDATION, ARGENTINA

2023

ABSTRACT[1]

Documenting policies and programs in Computer Science (CS) education is relevant as many countries face important gaps in computer literacy, particularly after the COVID-19 pandemic. While specialized pedagogical discourses have addressed the digital divide regarding infrastructure, the computer literacy gap has been scarcely mentioned. In this context, some countries are discussing how to move from offering CS knowledge in a segregated manner (to a few schools) to a "common" one for the entire universe of students attending compulsory school (Romero Moviñas, 2013). This report documents and systematizes educational policies and programs that governmental and non-state agencies have developed in seven Latin American countries —Argentina, Uruguay, Brazil, Paraguay, Chile, Costa Rica and Cuba— to introduce CS in the curriculum of compulsory education. The report also analyzes how each country faces challenges and the actions they perform to overcome them. It provides specific information on educational policy instruments and their development to strengthen the knowledge base on CS curriculum in the region. In particular, the report identifies (a) the current situation regarding CS education in each country, including how countries address educational problems with the introduction of CS (such as the digital divide, gender gap and technological dependency); (b) the challenges and tensions derived from curriculum reforms, and (c) curriculum content knowledge (CK), professional development and other programmatic policy strategies. Data sources include official educational agencies documents, research articles and interviews with key informants.

[1] Authored by M. Cecilia Martinez, Hernán Czemerinski, Natalia Iocca, Martín Torres y Mara Borchardt.

TABLE OF CONTENT

1.Introduction

Digital and computational technologies have become the most important means of production. These technologies assist in vaccine development, health diagnosis, climate and environmental predictions and energy saving models, among others, to name only a few fields where Computer Science (CS) makes significant contributions. CS algorithms also play an important role in profiling people to provide information, services and assistance. Knowledge of fundamental CS concepts is necessary to understand, participate, reflect and make decisions on computational processes that address sensitive topics affecting freedom, well-being, and basic human rights.

Given CS relevance, many educational systems have offered specialized CS education in schools (Romero Moviñas, 2013) or as an elective subject (Margolis, Goode & Flapan, 2017), benefiting a few self-selected students based on their previous digital experiences. This educational format is not addressing the digital divide in the appropriation of computational technology among students. The International Computer and Information Literacy study points out that 82% of high school students can effectively surf the Internet, manipulate images, manage passwords and perform other managerial and edition tasks. However, only 2% of the students can understand how a computer works to create new digital technology from it (Frailón, 2020).

The digital gender and socioeconomic divide is particularly prominent and seems to be wider in developing countries. In Latin American and other developing countries women account for ¼ of Internet users and about 18% of graduates in technological fields (Antonio & Tuffley, 2014; Gray, Gainous & Wagner 2017; Acilar & Sæbøç, 2021). Across the globe, the proportion of women working in computing careers is three times lower compared to other occupations and only 2% of patents in ICT belong to women (Mariscal, 2019).

In this context, countries are including CS for all students as part of compulsory education to democratize CS, bring more equity in terms of access to CS content knowledge and develop a workforce capable of producing national technology (Bocconi, 2016; Passey, 2017; Vega and Fowler, 2020). Schools have historically included "disruptive technologies" as mandatory content knowledge since they broaden our capacity to learn and understand the world around us (Simari, 2013). CS is a disruptive technology that allows processing a great volume of data — which is humanly impossible— impacting our life quality.

This report documents the main debates, approaches and educational policy instruments developed by seven Latin American countries regarding the introduction of CS into mandatory schooling. As many countries advance on this topic, they need information about possible educational policies, the challenges they face and the progress they have made.

2. Literature review on CS in primary and secondary education curricula globally

2.1. Theoretical framework

Educational research has analyzed how CS has been introduced into schools over the years (Bocconi, 2016; Vegas and Fowler, 2020). In the last two decades, the “integrated approach” to ICT (informational and communicational technology) dominated the educational arena, where digital technology supported the learning of traditional disciplinary subjects (math, language, sciences, etc.), and enabled access to worldwide information. The larger educational context emphasized transversal competencies over stand-alone curriculum subjects (Dussel, 2014). The transversal and competence-based curriculum has been criticized for diminishing the distribution of school content knowledge to new generations (Dussel, 2020; Del Rey, 2012) and undervaluing the deep conceptual structure of a discipline (Pardo, 2021).

Along with the approach to CS education, digital literacy has been defined as the ability to use technology. This concept has evolved towards understanding a language to produce technology; thus including coding or programming, which requires computational thinking skills (Bocconi, 2016; Wing, 2008; Köksaloğlu, 2022; Perez Paredes & Zapata Ros, 2018; Webb, 2017; UNESCO, 2019). More recently, digital literacy has included the notion of “computational participation” (Kafai, 2016), which involves developing computational applications that can contribute to community problems. A new concept of digital literacy distinguishes between representing information with different digital media and processing and transforming information through different programs. Computational participation is thus differentiated from Computational Thinking (CT) (Burke, Orian and Kafai, 2015). While CT has been related to learning about the potential of computing regarding data processing and automation (Wing, 2016), computational participation also implies creating applications by remixing and recombining code in a context of cooperation with open software communities to address computational problems that are meaningful to situated communities (Kafai, 2016). The current literature points out that schools should go beyond teaching how to use a computer to teach how digital technology is developed and how it works as well as its potential to solve computational problems.

Critical pedagogy perspectives have been included in the analysis of digital literacy to emphasize the emancipatory function of education addressing the structures and systems that produce inequalities and concentration of knowledge in the hands of a few (Romero Moñivas, 2013; Clear, 2004). An emancipatory education requires reflecting and understanding different phenomena to develop autonomy, responsibility and freedom. Following these frameworks, some authors analyze that the lack of CS content knowledge in schools limits students' understanding of how computer systems work although these systems influence our daily lives (Goode, 2010; Passey, 2017; Storte, 2019). For example, Vakil (2008) points out how the teaching of information security concepts focuses on individual responsibilities instead of analyzing systems vulnerabilities. Amy Ko (2020) makes explicit the limits and biases of computational systems that contribute to selecting and classifying people as well as producing and reproducing social inequalities. Along the same line, UNESCO (2018) argued in the Beijing Consensus on the need to introduce Artificial Intelligence content knowledge in schools with the purpose of both recovering a humanistic perspective in this field and promoting understanding of computational systems.

Other researchers showed that teaching approaches that emphasize work preparation select students that already have high digital capital, benefitting mostly white males (Margolis, Estrella and Goode, 2017). Similar processes were documented in Argentina (Echeveste and Martinez, 2022) where teachers selected males to do the programming of a domotic project and the project aesthetics were assigned to girls.

Other studies state that the selection of CS content knowledge is ideologically biased (Vakil, 2018) because in the name of pedagogical progress school include “current trends” in the curricula (Fattore, 2007). Curriculum selection focused on a liquid present that represented a culturally homogeneous sector in their consumptions and appropriations (Dussel, 2007). In turn, digital education focused on introducing computational practices required in the labor market and using private software instead of promoting access to open-source communities and their means of collaborative production.

Following Benjamin (2007), selecting adequate content knowledge is challenging since schools have three roles: they guard traditions, memory and the common culture, while at the same time, they include citizens in the present with knowledge that allows them to build the future. Due to these roles, curriculum decisions are always in tension. According to Dussel, *“the challenge is structuring an idea of common culture that can be shared and that notes the injustices and privileges of the past and at the same time could offer new ways to include diversity beyond the demands of the labor market and the self design culture.”* (Dussel, 2007, p. 23).

In addition, critical CS promoted the development of multiple teaching approaches to include diversity and a wider repertoire of content knowledge that addresses systemic inequalities, such as “Culturally Responsive Computing”, “Counter Hegemonic Practices” (Eglash, Bennett, Cooke, Babbitt and Lachney, 2021; Margolis, Ryoo, Sandoval, Lee, Goode and Chapman, 2012) and Critically Conscious Computing (Ko, Beitlers, Worztman, 2022). Educational policies at a large scale are taking longer to update their programs to reflect these new paradigms.

While theories offer new perspectives to introduce CS education in schools with an emancipatory and critical pedagogy, in practice, these new approaches share the CS education ecosystem with those that favor specific computational skills aimed at preparing the workforce or using computers (Bocconi, 2016). Some programs, such as CS for Oregon in the United States, have been developed with a strong focus on inquiry and equity-based pedagogy (Margolis, Goode & Flapan, 2017).

In summary, the concept of CS education has evolved throughout time and so has the research perspective on the field. Understanding educational policies and programs in CS education today requires recognizing its past, current and future perspectives. Thus, this theoretical framework provided our analysis with insight. This kind of work contributes to the existing literature on CS education analyzing educational policy development in Latin

American countries.

2.2. Background studies

There are a few studies comparing how countries introduced CS into the mandatory curriculum. Such innovation is a relatively recent concern dating from the last decade (Gal-Ezer & Stephenson, 2014; Furber, 2012). Vegas and Fowler (2020) reported that, out of 219 countries, only 20% have included CS content knowledge as a mandatory or elective subject in their schools.

Most of the reports comparing CS education across countries analyze policy instruments including curriculum, definitions of Computational Thinking (CT) and CS and their relation to school content, teacher preparation, teacher professional development and program evaluation (Bocconi, Chioccariello, Dettori, Ferrari & Engelhardt, 2016; Gal-Ezer & Stephenson, 2014; Jara, Hepp & Rodriguez, 2018; Martinez & Borchardt, 2021; Vegas & Fowler, 2020; Ithurburu, 2019; Jara, Hepp & Rodriguez, 2018). The main sources of data considered in the studies are documents, interviews and surveys made to policymakers.

These studies found that the introduction of CS into mandatory school is a recent problem. A decade ago, most countries offered CS content knowledge as an elective subject. Academics and policymakers shared weak consensus regarding the definition of CS as a discipline and CT. In general, countries define CT as general competencies and skills (such as algorithmic thinking, abstraction, finding patterns and breaking a problem into subproblems) or as a CS discipline that requires CS concepts. As a result, the place of CS content knowledge in the curriculum varies. The countries that define CT as general competencies tend to integrate CS into other subjects while those that define it as a disciplinary area include it as a stand-alone subject.

These studies point out that there are a variety of non-school programs (clubs, after-school programs, Internet sites) to introduce CS programming, a lack of teacher preparation programs and/or clear accreditation standards, and a weak program evaluation.

Only one report (Fraillon, Ainley, Schulz, Friedman & Duckworth, 2020) addressed students' CT abilities. The study assessed students from five European countries plus the Republic of Korea and analyzed students' performance on two levels: (1) conceptualizing problems that may be solved by computers, and (2) operationalizing solutions, by developing algorithms and programs. The results show that in these northern countries —with a strong tradition of equity in education— around 16% to 40% of tested students can solve problems at level 2.

In brief, previous work comparing educational policies in CS education is recent and documents the progress of a few developed countries. This study complements this line of work, focusing specifically on Latin American countries within this global context.

2.3.Methodology

The purpose of this report is to document policies and programs in CS education analyzing seven cases in Latin American countries. The selected countries met virtually at the first Latin American Symposium on Computer

Science Teaching in 2021 (Czemerinski and Gómez, 2022) to learn about their work experiences. Private, public and semi-public organizations represented the following countries: Costa Rica, Brazil, Uruguay, Chile, Paraguay, Cuba and Argentina.

Case studies enabled the analysis of policy instruments in their context. An in-depth analysis of each case related macro political processes to characteristics of local education systems and micro programmatic decisions. These debates allow us to think on potential policies for our own context.

These countries made relative progress in their educational programs in the field of CS education. Documenting educational policy instruments that have been implemented allowed us to understand their relative effectiveness and challenges. Data collection was divided into four phases.

Phase 1: Contact with participants from each country and general information questionnaire

During this phase, we held a meeting with participants who work at local organizations or governmental agencies responsible for policy development. The participants of the study completed an open-ended questionnaire that included the main areas of our policy analysis: program history, curricular approach, CS content knowledge, target population, professional development, materials, evaluation, etc.

Phase 2: Document data collection

Based on the questionnaires and documents provided by the participants, the team wrote case studies. Information gathered from research articles and other documents offered information about the implementation process.

Phase 3: In-depth interviews

A round of in-depth one-hour interviews with two participants from each country was conducted to complement and validate the data from the case studies. Participants were selected based on their role and time working on the program. Most participants have coordination, curriculum development and data analysis roles within the programs. They all have been in the organization for a long time and know the history and details of the program. To increase the validity of the study, the second participant was an “outsider” from the program development. Thus, participants included teachers and academics who did not participate in the development of the program but experienced the program in different roles. Teachers were selected by program informants and academics were identified based on the authorship of publications that were useful in developing the case studies. These interviews were extremely relevant to gather data on the process of developing policies and the program, and on the current state of the program implementation.

Phase 4: Validity

Finally, the case studies revised were sent to the participants. The purpose of this last round of revisions was to validate our interpretation of the data. Some participants provided interesting details and insights and updated the program status.

Data Analysis

Data analysis was concurrent with data collection. After the interviews, we prepared cross-comparison tables for each analytic area to systematize data and find patterns among countries. Emerging themes were identified from these tables, which are the basis of this report.

3.Description of national and regional policy contexts and approaches to CS

The digital gap between different socioeconomic groups in Latin America is particularly problematic. Trucco (2013) compared the use of computers among the high school students that participated in the PISA test (Program for International Student Assessment). While different types of uses are equally distributed among economic and sociocultural quartiles in most countries tested, in Latin America frequent users belong to the third and fourth superior quartiles and very few belong to the first quartile.

Part of the problem that hinders population access to technology is the region’s dependency on foreign technological development. Only 5% of Latin American exports belong to high-tech sectors. The strong dependency on foreign computational advances directly affects the region's capacity to find a specific path of economic growth compatible with social inclusion and sustainability (Suarez and Yoguel, 2020). The authors argue that, in the past, the need to sustain employment levels, maintain imports and exports balance accounts, invest in technology at productivity levels as well as disregard on equity and inclusion, have hindered technological growth in the region. Suarez and Yoguel suggest that productivity levels in Latin America had difficulties adopting new technologies due to the changes and learning curve implied in a context characterized by unstable markets. Within this larger context — and acknowledging how digital technology is central not only for economic production but also in other areas that improve the life quality of a population— Latin American countries are introducing CS into their mandatory school curriculum.

After examining the documents and discourses of the seven countries, it is possible to note a considerable variation in the development of programs and policy instruments. The coherence and articulation of the program's instruments largely depend on the country's prior efforts to introduce digital technologies in schools, among other factors such as educational system extension and governance. Another important variable that conditions program implementations is the governance structure of the educational systems. In countries where education decisions are decentralized in each of the states (federal systems of organization), program implementation is more diverse. A brief overview of each of the program's designs is presented below, which is organized in a spectrum that includes highly articulated programs —-whereby policy instruments are in place to provide a coherent curriculum implementation— to loosely coupled programs —whereby a few sets of policy instruments are being developed to include CS education.

The *National Educational Informatics and Computational Thinking Program* in Costa Rica is on one side of the spectrum. This program started in the late ‘80s as *Educational Informatics* and, since then, it has increased the number of schools participating in the program and evolved its curriculum. Nowadays, the program offers a specific curriculum for each educational level that includes CS concepts in preschool, primary, secondary and indigenous schools reaching 95% of the country's schools (Fundación Omar Dengo, 2018). Policy instruments include teacher preparation programs, curriculum guidelines, teaching materials, continuous professional development, ongoing teacher support and frequent evaluation and revisions (Fundación Omar Dengo, 2018). Since 1992, universities across the country have offered teacher preparation programs on educational informatics (Chaves Hidalgo, 2009).

Uruguay developed its *Computational Thinking* (CT) program in 2017 after ten years of uninterrupted provision of infrastructure, connectivity and digital teaching resources under the OLPC (One Laptop per Child) program, *Plan Ceibal*. The CT program has grown from 50 to 2,500 teachers in 2022, serving 30% of the targeted population from 9 to 12 years-old students (Anep-Ceibal, 2022). Policy instruments include teacher professional development, a CS remote teacher, in-school teacher support and teaching materials. Regarding the structure of teacher preparation, CT teachers receive professional development courses. One important background experience mentioned as relevant is “*Ceibal in English*”, a program that offers mandatory English lessons via video-conference with remote teachers. This model helps to overcome the lack of English teachers in the system. The CT program emulated this model, which was perceived as successful in Uruguayan schools. *Informatics* has been mandatory in the first and second year of secondary schools since 2012, when hardware and programming are taught. Students can also join the extracurricular robotics program offered in most public schools (Anep-Ceibal, 2022). The *Robotics Program* was established in 2010 for secondary school. This program equipped schools, trained teachers and supported robotics as an elective subject in many public schools, thus paving the way for the introduction of CS in school (García y Castrillejo, 2011). In addition, secondary school informatics professors are required to graduate from an informatics teaching program at teacher preparation schools. In addition, since 2008, general primary teacher preparation programs have included an informatics subject (ANEP, 2022).

In both Uruguay and Costa Rica, educational policies are centralized in the National Government; however, in the last years, Costa Rica has increased the autonomy and leadership of schools to introduce and adapt educational reforms (OECD, 2017). There are about 1 million students in the public system in Costa Rica, while, in Uruguay, there are around 750,000.

Argentina, Brazil and Chile developed national CS curriculum guidelines from 2015 to 2021 for compulsory primary and secondary education, after decades of educational technology programs that equipped schools and integrated the use of digital software in schools (Machiarolla, 2015; Bordignon, 2018; Oliverira, 2021; Ideo Digital, 2022). Although there are professional development and teacher preparation programs in the three countries, reports and interviews stated there are not enough prepared teachers to universally introduce CS in schools (García, 2018; Villalba, 2018). These countries have informatics education degrees at a university level and teacher preparation schools. In addition, they have offered professional development courses on implementing the new curriculum. Different organizations (Ideo Digital in Chile, Sadosky Foundation in Argentina and Centro de Innovación para la Educación Brasileña in Brazil) provide curriculum materials, workshops and training to teachers at a great number of schools within large and fragmented educational systems.

Argentina has about 10 million students in mandatory education (preschool, primary and secondary), Brazil serves about 57 million students and Chile has 3.6 million students. In these countries, educational systems are decentralized; this means that the implementation of such guidelines depends largely on regional efforts (Abreu, 2021). Thus, the teaching of CS varies within the country. The decentralized government of schools and large educational systems limit the scope of curriculum innovation.

Argentina has included programming as an elective subject in some secondary schools since 2012. The number of graduates from these schools is about 3% of the total secondary graduated population. Since 2018, all schools have been expected to introduce CS content at all educational levels, however, each state needs to develop a detailed curriculum as well as infrastructural and teaching conditions to make this happen effectively.

Similarly, Brazil included CT in the Common National Curriculum in 2018. To support these efforts, the non-state organization CIEB (Centro de Inovación Educativa Brasilera) developed a CT curriculum for reference that is being adopted by some federal states (CIEB, 2020). In February 2022, the National Council of Brazilian Education developed a CS curriculum complement addressing specific CS content for each educational level starting in 2023.

In the case of Chile, the program is designed as a pilot to gradually grow in the system and it is currently serving 80 schools (out of 11,000 in the country). Contrary to Brazil and Argentina (which added CS content transversally into the curriculum) Chile updated the area of *"Technology*", currently part of the mandatory school curriculum, to include CS content knowledge. The Chilean pilot program includes specific curriculum materials, professional development and in-school teacher support.

Finally, Cuba and Paraguay are working on a national plan to introduce CS in compulsory education. In Cuba, the National Government is designing the curriculum and leading teaching preparation for their 2 million student population. During the last two decades, Cuban schools have been receiving different educational software to promote learning in "hyper environments", which are multimedia platforms to learn different school subjects. In Cuban schools, there is an informatics subject in compulsory education addressing general digital competencies. One particular advantage of Cuba is its long tradition of teacher preparation in informatics at the university level that goes back to the late 80s (Hernandez and Cabezas, 2010). As a result, there is an important body of teachers who have graduated in informatics. The current efforts are aimed at updating the teachers' background to move from teaching the use of computer software to new methods of teaching CS that include algorithmic thinking and fundamental disciplinary concepts. A pilot program has been implemented since 2017 to gradually introduce CS and develop a new curriculum.

Paraguay Educa, a non-profit organization, makes efforts through curriculum, professional development and school workshops. Both Paraguay and Cuba still face large digital gaps in access to devices. In the case of Paraguay, previous digital educational programs were limited in scope. A recent report by the Ministry of Education in Paraguay indicates that only 65% of the population have access to the Internet and that devices are not always available at schools (Ministerio de Educación de Paraguay, 2021). Paraguay has developed its own OLPC program and the organization Paraguay Educa is offering workshops on CS content knowledge, but the scope is far from universal. Table 1 summarizes the main characteristics of these programs.

Country / Dimension	Responsible Actor	CS content throughout time	Target population
Costa Rica	Public-private partnership between the Public Ministry of Education and Omar Dengo Foundation (FOD).	Since 1988 without interruption. The program has gradually gained coverage and updated its curriculum to include CS concepts.	Compulsory education. Pre school, primary, secondary and Indigenous education. Ages: 4-16. Universal coverage.
Uruguay	National Administration of Public Education and Ceibal Foundation.	Since 2007, Ceibal has worked on infrastructure, connectivity and digital teaching resources. In 2017, the Computational Thinking program started.	Optional in public primary school. Mandatory informatics in first and second year of secondary school. Elective robotics.
Chile	Partnership between Kodea Foundation (Chile) and BHP Foundation (Australia).	Since 2015, Kodea Foundations has promoted CS education. During 2021, they underwent pilot tests in 80 regional schools.	Compulsory public education. Elementary schools (from 1st to 6th grade) and secondary schools (from 3rd to 4th grade). Gradual coverage.
Argentina	Public-private sector between the Ministry of Science, the Ministry of Education and Sadosky Foundation.	Since 2013, Sadosky has been promoting its Program.ar initiative. In 2008, the National Curriculum Guidelines included limited CS concepts.	Compulsory preschool, primary and secondary education. Implementation depends on each state.
Brazil	National Ministry, federal universities, regional agencies and private agency CIEB.	In 2018, the national curriculum reform included Computational Thinking. From 2022, National curriculum guidelines for each educational level to be implemented in 2023.	Compulsory education for students from 6 to 14 years-old. However, implementation depends on each state.

Country / Dimension	Responsible Actor	CS content throughout time	Target population
Cuba	Ministry of Education.	Since 2017 improvement of Cuba's National Education. It includes updates in the informatics curriculum to include CS.	Compulsory education from grades 3rd in elementary school through secondary school.
Paraguay	Public-private initiative with Paraguay Educa.	Since 2008, Paraguay Educa has promoted digital education. Currently, it is working on a plan to introduce Computational Thinking into the school curriculum.	N/A

Table 1. Main characteristic of the programs introducing CS content knowledge

The way policy problems are defined has implications for the types of instruments and reforms adopted for the educational system (Cuban, 2009). Thus, a first step to understand the program rationale is analyzing how countries defined their educational problems to support CS introduction.

3.1. Definition of the educational problem

Policy documents, regulations and interviews from the seven countries included educational issues to support the introduction of CS curriculum that were grouped and organized hierarchically into three problems.

1. Quality of their educational systems
2. Global demand for digital competence and literacy
3. Demand for a socio-productive system

3.1.1. Quality of their educational systems

The need to improve the quality of their educational systems is the main reason most surveyed countries support the introduction of CS in schools. These countries specifically address the following elements of the system: equity, student achievement, retention, curriculum relevance, and the need to overcome curriculum fragmentation. For example, the curriculum reform in Brazil was explicitly mentioned as a response to improve student performance and retention (Oliveira, 2021; CIEB, 2020). Brazilian authorities argue that isolated subject areas do not promote learning, thus, they propose reorganizing the curriculum into knowledge areas integrating technology. The "*Reference Curriculum*" proposed deepening students' technology knowledge so that they can actively participate in the contemporary world. The new curriculum also highlights the need to promote computational participation skills as more relevant than teaching "how to use a computer" (CIEB, 2020, p. 4). The latest curriculum reform in 2022 stated that including CS is necessary to develop 1) digital literacy, 2) computational thinking, 3) labor market demands, and 4) educational equity and inclusion (Consejo Federal de Educación Brasilero, 2022).

Regarding education quality problems, while high school retention rates in Latin American countries are increasing, they are still problematic. Appendix 1 compares high school graduation rates by income level.The pattern is similar in most of the seven countries. Half of the poorest population does not finish high school, while 80% or more of the richest cohort does.

Along the same line, discourses in Chile point out that, based on their own evaluations, most students do not reach minimal levels of computational skills (Vázquez, Bottamedi and Brizuela, 2019). The *"Ideo Digital*'' Project states that students need a new set of abilities to participate in a changing society, which include algorithms, knowing how to develop an application and understanding of how the Internet works (Ideo Digital, 2022).

Similarly, Uruguay proposes developing fundamental content knowledge to promote CT and problem-solving skills (Ceibal, 2019). Following Zamora (2012), Costa Rica also included CS to address a "quality crisis" during the '80s. Currently, the program aims at strengthening student achievement, computational skills and self-efficacy while reducing the digital divide, particularly, in indigenous and rural areas (Fundación Omar Dengo, 2018).

Paraguay also expressed the equity concern since its population is multicultural with large regions of indigenous descents. Paraguay Educa stated the need to promote understanding of CS technology for all regardless of language and culture. A culturally sensitive CS curriculum would help communities to create their own technology, enrich student learning and include all students in digital technology (Ministerio de Educación de Paraguay). Argentina also recalls inclusion efforts in the larger educational system to include CS, and Cuba is on the path to reform its curriculum to improve overall quality, according to what was stated by one of the interviewers.

In 2018, the International Computer and Information Literacy Study test (Frailón, 2019) assessed computational knowledge among students in two of these countries: Chile and Uruguay. The study ranked digital and computational skills of both Latin American countries below average. The study found that 0% and 1% of students from Chile and Uruguay, respectively, scored in level 4 of the test addressing understanding of how a computer works to create technology. On the remaining items assessed, the scores were below average. In addition, other quality indicators, such as PISA scores, are also below average for most Latin American countries (Schleircher, 2018). Thus, all surveyed countries recognize that improving the quality of educational systems is an urgent problem.

3.1.2. The global demand

Frameworks supporting the introduction of CS into the curriculum reference other international publications, which argue for globally including computational thinking or digital and computational literacy into compulsory schooling. The most frequent reference is Jeannette Wing's article on CT (2006), but there are other references to the International Computer Literacy Study (Fraillon et al, 2019) and digital literacy (Kong & Abelson, 2019; Shute et al, 2017). Curriculum reforms adopted in the countries studied follow international guidelines from countries in the North hemisphere, particularly, from the United States. Uruguay, Costa Rica, Brazil, Argentina, Paraguay and Chile explicitly mentioned following the ITSE curriculum (Educational Technology Standards and Performance).

Policy documents reflect on the need to improve the countries' education following the trend of educational system internationalization. Under the internationalization premise, the local context includes a global dimension so that citizens can improve their regional conditions based on global systems and ideas as well as participate in global environments. Curriculum, accreditation, and school format and regulation have been applying internationalization standards from the last century, but mainly after post World War II, when education was recognized as a basic universal human right. Policy documents from the UNESCO, PISA, OECD, IBD, United Nations, World Economic Forum and UNICEF are frequently cited in the national policies supporting CS curriculum.

While curriculum programs follow international guidelines and projects, world wide agencies have not strongly supported CS education yet. Thus, rather than a top-down influence, whereby more powerful agencies impose innovation on other agencies that follow their orientations, we believe that this particular process responds to the internationalization of education in terms of including educational programs from a global perspective, but responding to regional needs. In this case the most important need is improving the quality of educational systems and closing the digital divide.

3.1.3. Demands for a socio-productive system

Finally, the third main reason for countries to include CS is to address the industry's current and future demands. Uruguay, Brazil, Argentina, Chile and Costa Rica state the need for an industry and labor market, either in their documents or interviews. However, this reference is not as vital as improving the quality of the educational system and addressing global preparation. Costa Rica has a specific program (in addition to the compulsory curriculum for all the students) to address preparation for the market. The program is called "*4.0 Industry employability and works of the future*", and it offers specialized knowledge and, in some cases, it provides certification.

3.2. Countries' general approach to CS education

Considering different educational policy contexts, but with similar educational problems, the countries we studied are defining a series of policy instruments to support CS implementation in their compulsory education. Table 2 summarizes the main policy instruments.

Country	Regulations	Curriculum	Teacher preparation and requirements	Relation with the educational system	Evaluation of the program
Costa Rica	National law recognizing the program, including budget	Stand-alone subject. Detailed curriculum for each educational level, which includes weekly lessons of 80	Requirement of a university degree in Educational Informatics. Programs have been recently updated to include new approaches to teach programming and CS. Omar Dengo Foundation (FOD) offers	Mandatory for all educational levels. Gradual school coverage since	Frequent evaluation of the program from internal and external evaluators throughout the years. Evaluations were key for

	provisions	minutes.	school visits, courses on informatics and continuous teacher support.	1988. FOD works on a school basis.	improvements.
Uruguay	National law recognizing Centro Ceibal and its programs. No specific regulation on CS education.	Primary: integrated CS content with math, language, arts and science. Detailed problem-based learning lesson plans. No national curriculum. Secondary: stand-alone subject in first and second year.	In primary school, the program offers a co-teaching model. A remote teacher, who specializes in CS teaching, offers video conference lessons, together with the classroom teacher. Plan Ceibal provides online courses on Computational Thinking and in-school support to classroom teachers in the program. In secondary school, a degree in informatics education is required.	Elective for elementary schools teachers serving students from 9 to 12 years-old. Gradual school coverage. Required in the first years of secondary schools.Then, robotics is elective.	Frequent internal evaluation of the program for the purposes of scaling up. International organizations participate in the evaluation (for example, Brebras and ICILS).
Argentina	National Curriculum Guidelines in a federal system.	Each state can choose to include CS content as either transversal, integrated or stand-alone subject. Sadosky Foundation provides CS teaching textbooks.	Tertiary degrees in diverse programs addressing technological processes are required to teach informatics at schools. Since 2013, Sadosky Foundation has partnered with national universities to offer professional development courses and two-year programs on CS education.	Mandatory for all educational levels, although the implementation depends on each of the 24 states. Elective in some secondary schools with focus on programming.	Sadosky Foundation has evaluated their own programs (textbook material, teacher preparation and professional development programs). There are no national evaluations of the guideline implementation.
Chile	No specific regulation on CS education.	Ideo Digital proposed to update the Technology curriculum to include CS content knowledge. Stand-alone subject	In-service teachers participating in the program were offered a twenty-hour bootcamp provided by Ideo Digital facilitators. Facilitators then supported implementation in school for six-hour per month.	Although CS content is not mandatory, most schools are expected to adopt it and deliver within the Technology subject.	The pilot has been evaluated and, consequently, teacher professional development programs have changed.
Brazil	National basis for a common curriculum (2018) and a complement to CS education (2022)	CIEB developed reference material to support the 2018 reform. The 2022 CS curriculum complement includes detailed CS content knowledge for each educational level.	There are teacher preparation programs on CS in a few universities, although graduation rates are very low and not enough to supply the system. CIEB offers self- assessment digital competence instruments. The government and other organizations offer online courses on CS education and maker culture.	Content will be mandatory for all schools and at all the levels in 2023. Implementation depends on each of the states.	CIEB knows which states are adopting the reference curriculum. However, there is no systematized information at the moment.
Cuba	National Resolution in 2015 approving pilot experiences that include CS content.	Informatics has been a stand-alone subject since the late 80s. National improvement to include CS concepts.	The post-graduate secretary of education offers online courses on robotics, algorithms and programming with Scratch. The focus of courses is both pedagogy and content. A degree in informatics program is required for teaching.	Content will be mandatory for all the educational levels. Since 2017, a pilot program has been expanded to more than 150 schools.	The pilot program is being evaluated, although there are no official reports.

Paraguay	CS introduction is under analysis as part of the National Plan for Educational Transformation.	Currently, CS is offered as an extracurricular course at a few schools by Paraguay Educa.	Paraguay Educa offers workshops on CS programming. Scope is limited.	Not defined.	Not defined.

Table 2: Policy instruments to introduce CS education in each country

One theme emerging from the study is that the countrys' approach to introducing CS into their curriculums varies. The hierarchy of content knowledge in the curriculum is given mainly by the relation between the subject and graduation requirements (compulsory or elective) and the organization of content in the curriculum (stand-alone, integrated, transversal or extracurricular subject). Although at the moment of this report half of the countries surveyed place CS as an integrated or transversal subject (Uruguay, Brazil, Argentina), representatives from these countries reported that they are moving to establish CS as a stand-alone subject. For example, Brazil has already approved a curriculum complement to make it a compulsory and stand-alone subject. Uruguay is planning a specific curriculum for high school. In the case of Argentina, several states have already been developing compulsory guidelines for secondary school.

Another interesting finding is that most countries are taking a gradual approach to introduce this content, thus policy instruments are in constant evolution. For example, Costa Rica has improved its program in terms of content knowledge and school coverage decade after decade. Chile and Cuba started the program with a set of experimental schools and are planning to extend it to more regions. Argentina passed the National Curriculum Guidelines, and each state is updating its Federal Curriculum to introduce CS with a detailed orientation to content knowledge at each educational level. Uruguay is gradually increasing the number of elementary schools that voluntarily adopt the *Computational Thinking* program. Brazil has developed general national standards in 2018, but it has elaborated a detailed complementary curriculum for 2023. Cuba and Paraguay are also working on National Curriculum Frameworks.

Countries took programmatic decisions depending on each educational system's conditions and possibilities. Introducing formal regulations requires reaching a consensus on the educational policy arena. Introducing digital technology was controversial in countries where there is no consensus on what type of technology and content should be best for students. Changing curriculum organization and investing in teacher preparation also require strong political decisions in countries with other emergencies in the educational system, such as school attendance and promotion. Each country makes different programmatic decisions based on all these factors.

Finally, a loosely articulated policy instrument is teacher preparation and professional development. While Costa Rica has three articulated actions —teacher university requirements, continuous professional development and in-service support— other countries are offering limited opportunities to train teachers on CS education. The following section provides details on the implementation approaches the countries adopted.

4. Analysis of national and regional CS implementation practices

This section highlights the agencies' programmatic decisions on program implementation.

4.1.. Different agencies participating in program development

One interesting finding is that in all the cases — except for Cuba— there are non-state actors as well as science and technology agencies leading initiatives to introduce CS curriculum in schools. These agencies support educational policies with the following policy instruments: curriculum frameworks, teaching materials and professional development, regardless of whether the system is centralized.

In Costa Rica, the Omar Dengo Foundation (FOD) has led efforts in the national informatics program since the late 80s, and the government has assigned the foundation to run such a program in the last decade. This Foundation is responsible for the program implementation, and a national law recognizes its role. The participants of the study reported that academics, businessmen and policymakers, working closely with the Ministry of Education, had the initiative to include informatics in the system and founded the organization under two assumptions: a) the Ministry of Education did not have the capacity to develop and execute such a program, and b) introducing a curricular area entails long-term efforts that are far beyond the political terms of four years without re-election. Thus, the organizers thought a foundation was strategic to sustain the program.

In Uruguay, Plan Ceibal Foundation has led the OLPC program since 2007 and is currently leading the *Computational Thinking* programs in elementary schools. This organization depended on the Ministry of Industry in its earlier beginnings and, in 2021, it was restructured to be part of the National Public Education Administration (ANEP).

In the case of Argentina, the Sadosky Foundation — dependent on the Ministry of Science and Technology and the private sector— has developed curriculum materials, professional development programs and policy documents to inform policymakers in education about the need for CS education. The Foundation's work has allowed the inclusion of CS into the public agenda.

In Brazil, the non-state organization CIEB (Center for Innovation in Education in Brazil) developed the first curriculum as reference to introduce CS in 2019. In addition, in 2022, the National Council of Education gathered a group of professors and academics across the country with the help of the Brazilian Computer Association —a group mainly composed of academics on CS— to develop the mandatory official curriculum standards to introduce CS at all education levels. Both organizations have been relevant to promote public discussion on CS education.

In Chile and Paraguay, the organizations Idea Digital and Paraguay Educa are developing curriculum proposals while offering CS teaching materials, professional development and workshops for schools. In the case of Chile, Fundación Kodea has selected curriculum materials, designed teacher training programs and carried out different actions to raise awareness among the educational community of the benefits and feasibility of including CS in the country's public school system.

In all these cases, non-state actors worked on different efforts (mostly teacher professional development and teaching materials) long before Ministries of Education considered introducing CS content into their curriculum. In Costa Rica, Uruguay and Chile, the government made alliances with these organizations to expand their initiatives and give them public policy status. An analysis of the implementation process shows that, when non-state actors gain official governmental recognition, they have the potential to scale up the program in public schools (which is the case of Costa Rica, Uruguay and Chile). If not, their efforts remain of important innovation but limited in scope, such as in the case of Argentina, Brazil and Paraguay. One interesting outcome of many of these agencies is the introduction of formal legislation or curriculum regulations. However, although these three countries are making relevant progress to include CS —-specially considering that their educational systems are large, unequal and decentralized— the implementation of educational practices in CS education is fragile without the status of educational policies, which brings legitimacy and resources. Most struggles relied on reaching a larger set of schools.

4.2. Networks of collaboration informing policies and providing continuity

One emerging theme is that all the agencies leading the introduction of CS curriculum have developed a network of collaboration, which has been relevant to provide a theory of change (theoretical foundations about the need and process for change), and capacity for change (human, social, symbolic and economic resources to make change). Each case is explored below.

In the case of Costa Rica, the length of the program, their international networks and constant monitoring and evaluation efforts have supported and improved CS teaching practices. Professors of the Massachusetts Institute of Technology collaborated in the program from the very beginning. Currently, the program is working with the Computer Science Academy from Carnegie Mellon University, the Media Lab MIT, the Scratch Institute, among other partners such as CODE.org. These organizations have been leading CS teaching innovations for the last four decades.

Similarly, in Uruguay, Ceibal is part of *New Pedagogies for Deep Learning Global Alliance,* a prestigious organization led by the recognized Canadian educator, Michael Fullan. Only six other countries participate in this alliance: Australia, Canada, the United States, Finland and New Zealand. In this global network, technology plays a central role in promoting meaningful and “deep” learning. The network offers models to analyze and evaluate teaching practices, allowing each school to improve based on their own reflections. Specifically, the CT program is designed based on meetings held with Ceibal officers and their international peers from MIT and Stanford University. Ceibal also works with the Bebras program, from Estonia, the British Council and Code.org. Regionally, since 2019, it has been consulting with Sadosky Foundation, from Argentina, and educational technology organizations, such as Gurises Unidos (united kids), El Abrojo, Chicos.net, Conev, Alianza, Playbot and Aonia. These organizations contributed to the development of the curriculum and evaluation materials.

The Ideo-digital program, in Chile, is a mixed initiative involving the Chilean Kodea Foundation (created with links to Code.org and many local partners) and the Australian Mining company Foundation BHP (Broken Hill Proprietary). Mining is Chile's most important economic activity. Kodea is mainly responsible for curriculum development, professional development and teaching materials; but receives financial support and teaching materials from the other organization mentioned above.

Argentina, Brazil, Paraguay and Cuba's programs relied on national networks rather than international ones. For example, Sadosky Foundation, has developed teaching materials, teacher preparation programs and CS educational research as well as it has made alliances with national universities across the country. The rationale for making these alliances was to develop CS education research groups within the universities that could continue the development of CS education as an area of study and outreach within the country, even if the government discontinues the program. Given that it is very often that governments discontinue programs in Argentina, this strategy is particularly relevant to provide sustainability and growth. Another reason to have universities as allies was that they could scale up the program in each state by providing trainers and human resources to develop teaching materials. Sadosky has financed projects that universities submitted in different calls for proposals. As a result, the program has reached 22 states (out of 24) and 5,000 teachers. In addition, Sadosky collaborates with different state governments regarding teacher preparation and curriculum development. Sadosky also collaborates with Paraguay, Costa Rica and Uruguay on the development of teaching materials. In particular, Sadosky's textbooks on CS in the classrooms are being used in many countries in Latin America and districts with large hispanic populations in the U.S.

The CIEB, in Brazil, had made national and international alliances to support educational technology in general. To develop the national CS curriculum complement, the government has convened actors from many different sectors in a *National Special Committee of CS Education*. Participation in this committee included:

- Eight organizations on pre-school education,
- Eight academics from federal universities, experts on the first years of primary education,
- Ten academics from federal universities, experts on the last years of primary education,
- Eleven experts from universities and other public agencies, who focus on secondary education,
- Eight experts from federal universities, who study continuous teacher development, and
- Eight experts from different universities, who validate the curriculum.

Together, they elaborated a detailed curriculum on CS education for every level of the educational system, which has federal recognition and support.

Paraguay Educa collaborates closely with Plan Ceibal from Uruguay. Locally, they are part of the following national organizations: Citizens Observatory, Childhood and Adolescence Group, and Coordination for Infancy and Childhood.

There is coordination among Cuba's Ministry of Education, the Central Institute of Pedagogical Sciences, the Secretary of Educational technology and state universities to develop and validate the new CS curriculum.

In all the cases, the networks provide specific knowledge and expertise on CS education, bring diversity and legitimacy, and allow scaling up the program. Most importantly, these networks of collaboration support the program implementation, offering resources such as teaching materials and professional development models. These networks are also relevant to improve the programs throughout time based on new research and perspectives.

4.3. Reaching a consensus on what Computer Science includes

Despite being often associated with programming, CS is a broader field of study that encompasses many other subfields: Computer Networks, Data Representation and Artificial Intelligence are just a few examples. Reaching a consensus on what to teach is always a big enterprise. After a careful analysis of all the curriculum programs, we found that the programs we studied address the following subfields: *(i)* Algorithms and Programming; *(ii)* Computer Architecture and Hardware; *(iii)* Computer Networks; *(iv)* Security; *(v)* Data representation; *(vi)* Data Structures; *(vii)* Artificial Intelligence; *(viii)* Operating Systems, and *(ix)* Digital Citizenship. In addition, the analysis divides the educational stages as follows: preschool (children from 0 to 5 years-old), elementary school (6-11 years-old) and secondary school (12-17 years-old).

In all the countries, *Algorithms and Programming* is a central part of what is being taught at school (or planned to be taught) in both elementary and secondary school. The exception is Paraguay, where, although it is under consideration, the country still lacks concrete definitions regarding curriculum design. It is worth noting that Costa Rica, Brazil and Argentina also include algorithmic and programming concepts in preschool. Besides, there is a trend to develop programming skills not only by coding software that runs in a classical computer, but also by using actual physical robotic artifacts. An interviewed teacher from a rural boarding school in the mountains of Costa Rica mentioned that she focused on teaching logic and mathematical thinking, problem-solving and modularization by using tools such as Scratch, Makey Makey or Microbit. When asked about other CS areas, she replied that programming is the most relevant CS content taught.

Digital Citizenship is also a topic addressed by almost all the countries during both primary and secondary school. It is only left out by Costa Rica (and possibly Cuba, which is not mentioned in the available documentation). In addition, topics related to *Computer Architectures and Hardware* are considered in most countries (except for Chile and Paraguay). Costa Rica includes them during the three educational stages: Brazil in preschool and elementary school, Argentina in elementary and secondary school, and Cuba and Uruguay in elementary school. *Computer Network* concepts are also taken into account by nearly all the countries: Uruguay (elementary school), Costa Rica (secondary school), Brazil, Argentina and Chile (elementary and secondary school). Additionally, *Artificial Intelligence* contents are present in different countries: in Chile, Brazil and Argentina in secondary education, and in Uruguay in elementary education.

The remaining CS subfields are being considered only by a few countries: *Data Structures* is only addressed in Brazil (elementary and secondary education); *Data Representation* in Chile and Brazil (in both cases, elementary and secondary education), and *Security* in Chile and Uruguay (elementary education) and Brazil (elementary and secondary education).

The countries have developed (or are developing) their curriculum according to local criteria that address local issues and follow international curriculum guidelines. The only exception is Chile, which proposes adopting the off-the-shelf curriculum designed by Code.org.

According to the study participants, the criteria to introduce the mentioned topics at different educational levels respond to the system possibilities. For example, in some countries it is easier to introduce innovations in elementary schools because they have an organizational structure that allows including new content and new teachers. Also, it is possible to start with programming because there are more teaching resources available in that area. However, the long-term goal for all countries is to introduce CS as new literacy and thus, as mandatory at all educational levels.

Scratch is, by far, the most widespread language to teach programming in all cases. It is a block-based language that provides a friendly interface to develop software projects. Costa Rica is the only country that also promotes the learning of a text-based language (Python), which is closer to what is used in the software industry. It is worth mentioning that Argentina and Costa Rica developed tools for teaching programming: Pilas Bloques and Gobstones are currently used in Argentina, and RobiE++ and Titibots in Costa Rica.

Chile, Uruguay and Paraguay import contents and teaching materials from abroad, while the remaining countries design their own. Interestingly, the Sadosky Foundation, in Argentina, developed teaching material that includes topics such as *Operating Systems*, *Data Representation* and *Security*, which, although they are not part of the country's current curriculum, are being adopted by many schools. A table in appendix 2 summarizes curriculum information, which is organized by country and includes all the bibliographic references.[2]

In most of the cases analyzed, the program offered a selection of CS content knowledge and areas that are expected to be implemented in schools. Teachers did not participate in deciding this content in any of the cases analyzed. Contrary to other countries where teachers have a long tradition of rigorous preparation at universities on

[2] A table that summarizes curriculum content of all countries is available at https://tinyurl.com/2nte6j9a.

the subject matter and pedagogy, in most Latin American countries, preparation is offered in Teachers Preparation Institutes at a tertiary level. Moreover, as mentioned earlier, entry requirements for CS teaching positions do not require a deep and solid preparation in CS. Thus, in light of a short tradition of teacher preparation in CS education, their participation in deciding CS is limited. The lack of teachers' input in developing a curriculum has its downsides, hindering the legitimacy of its implementation.

4.4. Evaluation provides accountability and information for improvement

Only four of the countries surveyed in this study evaluated their CS education program: Costa Rica, Uruguay, Chile and Argentina. In these countries, the programs have been in place for three decades, seven years and one year, respectively, but evaluation was part of the program design. These organizations are evaluating their professional development, curriculum instruments, scope of the program and, in two cases, student learning.

Cuba is conducting an evaluation of its whole educational system, which includes the teaching of informatics. This evaluation is informing the development of the new CS curriculum. Brazil and Argentina —the most decentralized educational systems of all the seven countries researched— do not have a national monitoring system in place for CS education. In Paraguay, a national policy is still under development.

In the case of Costa Rica, the program was formally evaluated by the Ministry of Education in 1993 and 2010. In addition, the FOD carries out its own evaluations (see Fonseca 1991 and Fundación Omar Dengo 2007, 2016, 2018, 2022) and allows international agencies, including the World Bank, UNESCO and UNICEF, to also conduct case studies. In 2018, the FOD conducted an extensive evaluation for the 30 years of the program. In particular, this evaluation showed how the program contributed to providing technological infrastructure and Internet to schools, the number of teachers who received professional development, and students' skill development. Through a test that assessed problem-solving, productivity and communication, the evaluation showed that, besides the family's cultural capital, the number of years in the informatics program is a variable related to achievement in these three areas (FOD, 2018). The report also showed how the program improved self-efficacy, among other achievement indicators. Interviewed participants mentioned that, during conflictive times when the program was jeopardized, evaluations and the program public support were key to providing continuity.

In Uruguay, Plan Ceibal evaluated students using the international Bebras Challenge in 2020. From a sample of students, the evaluation found that students' participation in the program was correlated with learning programming skills (Koleszar, Clavijo, Pereiro, 2021). In addition, the report "Ceibal in Numbers" (Ceibal, 2019) analyzed the scale and scope of the program. Approximately, 30% of students from 9 to 12 years-old in the country have received CT lessons. After each lesson plan, there are student evaluations on an online platform. All this data informs the program. They allow understanding students' learning and challenges to make changes and improvements in teaching materials, which are one of the main instruments to bring CS to schools. Another line of evaluation assessed the teachers' program appropriation. Based on interviews, teachers reported that the CT program contributes to general student learning and student motivation. Teachers also mentioned that the program requires a different way of working in the classroom, including an articulation with remote teachers. CT projects are organized interdisciplinary, which was a requirement during the pandemic. Teachers mentioned the project reduced a large part of workload. According to the interviews, teachers mentioned *"You don't have to think about the project problem, it is already there, you just need to add the content."* Besides, the educational community recognized that this program contributes to equity since it provides resources that previously were only available in private schools. Another important indicator of the program is that many families ask schools to adopt the program and, as a result many teachers start participating in it.

Chile is carrying out a pilot program at a small scale. During 2021, a Chilean University was selected to conduct an external evaluation of such a pilot. The evaluation included interviews, focus groups, observations, and pre and post tests. Based on this data, the program has changed its professional development model to support teachers more closely. They plan to continue evaluating the pilot.

In the case of Argentina, Sadosky Foundation has analyzed its professional development programs and the use of teaching materials by hiring an external evaluation agency. The evaluations studied the scope of each instrument in every state used, teachers profiles and learning. Data collection included teachers' surveys, classroom observation and records of professional development registration and attendance. Results showed great diversity in teachers' appropriation of content and materials, but positive results regarding the perception of the programs. The other countries have not monitored their progress.

The lack of formal or planned evaluation affects program implementation since, for most countries, results and school needs to implement CS are not rigorously documented.

4.5. Change agent

The organizations have selected different change agents as part of their program rationale. In the cases of Costa Rica and Chile, the program works on a school basis. Uruguay and Paraguay Educa work on a teacher basis since registration to CT programs is voluntary. Brazil and Argentina seem to work simultaneously at a state level (given the federal and decentralized systems) and on a teacher basis. In turn, Cuba offers a more systemic approach to change.

One characteristic of the informatics program in Costa Rica is that FOD, together with the Ministry of Education, has selected schools to participate in the program. During the process of selection, the FOD and Ministry of Education analyzed the school infrastructure and, based on this analysis, they provided the means to technologically equip the school to implement the program. Once the school administrators equip the center with computers and connectivity, FOD invites them to formally participate in the informatics program. Interestingly, the program worked on a school basis, engaging principals and other administrators in the conversation, rather than on a teacher basis. This practice is relevant to support the introduction of any educational innovation, but particularly educational technology since one of the most important variables promoting teachers' adoption of a new program is that their colleagues and institutes support the program (Ertmer, 2005).

A similar case occurred in Chile, where the program selected a few schools in the region to introduce the new CS curriculum. Then, the school selects teachers, and the in-service professional development model allocates teacher facilitators to help classroom teachers in the school with several visits throughout the year.

In Uruguay, Argentina, Brazil, Paraguay and Cuba, teachers voluntarily enroll in the program or in professional development courses to learn about CS introduction into the classrooms. In addition, Sadosky Foundation in Argentina and CIEB in Brazil have worked together with federal states that voluntarily want to redesign the state CS curriculum or adopt the organization's teaching materials. Both models of change respond to the country's structural educational organization. In these countries, where the agency of change is the school, teachers have better conditions and support to introduce CS content knowledge. Investing solely in teachers, disregarding working conditions and school expectations of what digital education should be, hinders the implementation of CS content knowledge. In many cases, trained teachers work hard to introduce CS education, but the school administrator and other teachers demand more teaching of ICT instead. Other problems are related to the technological conditions needed to introduce CS content. By the same token, agencies do not have the capacity to work with schools, particularly when these agencies are non-state and, thus, do not have formal ways to require school participation.

4.6. The centrality of professional development

Together with the curriculum, a key element in bringing CS education is teachers' professional development. Only Costa Rica and Cuba require informatics teachers to hold a university degree in Informatics. While the remaining countries offer CS education programs at university levels, they all reported that most computer scientists prefer to work in the industry rather than in schools and the few who graduate from universities cannot even supply the growing IT industry. Thus, all countries have opted to train teachers in the job based on different models.

Costa Rica has offered CS teacher preparation in more than seven universities in the country since the '90s when the educational informatics program started. Recently, FOD has participated in the update of teacher preparation programs to include Python, Robotics and Electronics. In addition, one of the external evaluations pointed out that, in this country, teachers needed continuous support (Jara, 2018). To address this topic, the PAD (Plan de Actualización Docente or Teacher Update Plan, in English) includes diverse activities, such as virtual courses, workshops, in-person courses and teaching resources. The Ministry of Education supports and invites teachers to participate in these developments providing them with the status of a public policy. All the programs follow a constructivist approach to CS learning, since teachers are expected to also deliver the content under this approach.

Teacher preparation institutions in Uruguay offer Informatics Education. The four-year programs include pedagogic and disciplinary content. For the CT program, Ceibal offers online and in-person forty-hours courses for each of the teaching units included in the program. These courses allow teachers to experience at first hand how the teaching project will be developed. Programming and pedagogical strategies are discussed. In addition, Ceibal offers in-classroom support for CT teachers.

In Argentina, Sadosky Foundation has organized professional development programs, together with universities and provincial ministries of Education, to reach a large part of the country. These courses offer introductory programming for primary school level and have a duration of seveny hours. The most recent evaluation documented that 22 states offered courses, working with 40 universities and reaching 3,959 teachers and 1,300 principals. In addition, the Foundation and universities have offered two-year programs on CS education designed for participants holding a teaching degree. The goal of these programs is to leverage the capacity of teachers in the system, specializing them in CS teachers. Upon identifying that teachers' implementation of CS curriculum depended on school administration's support, Sadosky offered between the years 2018 and 2020 courses for school principals and vice principals in several provinces.

The official website of the Brazilian Ministry of Education offers more than 150 courses on CS education. During the interview, a Brazilian academic who participated in curriculum development, mentioned that such development depends on the teacher's voluntary actions. The country has no systematic plans for teacher preparation in CS education, mainly because, at the time of writing this report, CS content knowledge is offered transversally.

Paraguay Educa, the Government of Cuba and Ideo Digital Chile have offered professional development courses with a duration between forty to ninety hours to small-scale teachers participating in their pilots. Teacher preparation in CS education remains one of the great challenges.

5. Analysis of the potential of CS and its challenges in Latin America

Five main challenges arise from this analysis.

5.1.Defining CS as a discipline

A theme emerging from the interviews — which helps to explain how regulation is developed— is the lack of consensus on CS disciplinary status and definition and, based on those variables, the selection of content knowledge to bring to schools. The responses given for each country are described below.

In the case of Costa Rica, it was reported in an interview that the name of the program has evolved from Educational Informatics to Educational Informatics and Computational Thinking to reflect the update of the content. Chavez Hidalgo and Berrocal (2009) also reported that, although the curriculum has always been focused on CS education in Costa Rica, other content knowledge related to ICT education was introduced in the '90s. The curriculum was revised in the last decade to strengthen CS content. Some studies showed that teacher preparation programs at universities in Costa Rica had favored informatics application in education, rather than CS education and computer programming languages (Chaves Hidalgo and Berrocal, 2009). As a result, the participants of the study mentioned that FOD is also working on updating teacher preparation programs to include CS and its subareas.

Uruguay's CT curriculum has evolved throughout these years. Respondents to the interview mentioned that, at the beginning, CT was thought of as a set of general problem-solving skills decoupled from CS concepts. The CT educational projects required, for example, dividing a scientific problem into subproblems, but without the formalization of its terms as CS requires. New teaching materials show that the program has recently revised its unit plans to specifically include CS concepts. In addition, the CT program has added different CS subareas beyond programming to include Artificial Intelligence.

The National Curriculum of Argentina and Brazil address general CS competencies, together with digital competencies closely related to ICT education (such as sound edition, using a digital camera, etc.). In Brazil, a special national commission has already made a curriculum complement to national bases to include CS content. A CS academic, who participated in the process of developing this complement, mentioned during our interviews that the special commission discussed for a long period what CT and CS were. In addition, academics had to educate the rest of the educational community regarding the fundamentals of the discipline.

A similar case occurs in Argentina, where the educational community has to be educated about what CS is. A teacher interviewed, member of the National Informatics Teachers Organization (ADICRA), mentioned that the notion of "digital natives" — which argues that students are knowledgeable about the digital world based on their date of birth— and the notion of "CS is a transversal discipline" severely inhibit the implementation of CS content knowledge. Informatics teachers also mentioned being "attacked" (verbally and symbolically) by the open-source community, arguing that CS educators want the "exclusive" use of computers. This teacher mentioned he had to educate policymakers and the large educational community on what CS is. The same comment came from a Brazilian teacher interviewed. One possible hypothesis is that this concern is linked to the definition of CS. When CS is defined as a set of skills and a tool to promote the learning of other subjects, the assumption is that all teachers could and should teach those skills. In contrast, the lack of consensus arises when CS is defined as a specific discipline with its own conceptual structure, such as when math or geography are defined. The latter definition has direct implications for what concepts should be included in an informatics class and who should teach them.

In addition to the problem of reaching a consensus on content knowledge, the high demand by the educational system to include ICT and other kinds of technology from a perspective emphasizing the production and design process limits the amount of time to teach CS. Both CS teachers interviewed from Brazil and Argentina, where CS is a transversal content, mentioned the same phenomenon: there is no time and place in the curriculum to introduce CS in schools until there is a regulation of a stand-alone subject. In one teacher's words, CS content knowledge "competes" with digital technology content (such as sound or video edition), which has already been legitimized in the curriculum and in the school cultures. In both cases, these very committed professors described that they address general problem-solving skills during regular school hours, such as dividing a problem into subproblems. Only during the after-school program, they teach CS content knowledge, including algorithms, programming, informational security and other CS areas. In addition, technology teachers are required to teach different technologies. An interview with a policymaker in the area of educational technology mentioned that the Technology curriculum does not address any specific technology (such as digital or computational) but all technologies. She specifically emphasized that technology diversity is desirable, and mentioned solar energy and electric energy as examples. In this curriculum structure, digital and computational technology do not have any special prevalence over other technologies. The fragility of the CS definition and the lack of recognition as a technology enabling the development of other technology (for example, CS makes energy management efficient and possible) have consequences on teaching practices in the area and, ultimately, on the scope of students receiving this content knowledge.

5.2. Preparing teachers to include CS in all targeted schools in a timely manner

Preparing teachers to teach CS is the main problem according to research articles and interviews. Regarding the kind of professional development that is offered, there are four main models that, in some cases, work simultaneously: 1) teacher initial preparation at universities or educational schools (Costa Rica and Cuba); 2) CS subjects in teacher preparation programs (Uruguay and Costa Rica); 3) professional development courses (Brazil, Uruguay, Argentina, Paraguay and Chile), and 4) in-school teacher support (Costa Rica, Uruguay and Chile).

A common pattern among the cases is the perception that teacher initial preparation is outdated or insufficient. In the studies reviewed, interviewed teachers mentioned that the teacher preparation program had not prepared them to teach CS through projects or problems. They also perceived that teacher support was not enough.

In Uruguay, a survey among teachers who participated in a CS professional development program was conducted, whereby 50% of the teachers mentioned that while the quality of the course was good, it was not enough to implement the program. Besides, half of the teachers surveyed preferred online settings to adjust their own schedule, and the other half considered in-person development more effective (Villalba, 2018). Teachers in this study especially valued courses that could be applied to teaching. Villaba found that Ceibal teachers —and special teaching support positions— felt overworked. By the same token, the teacher who received the Ceibal program felt that support was not enough (Villalba, 2018).

Analyzing the position of regular teachers who coordinate programming and robotic clubs, but with no CS background, García (2018) found that teaching without knowing content knowledge is seen by teachers as a “natural phenomenon”. These teachers assume that it is valuable for students to receive robotics even if they cannot teach it. Students, families and peers value teachers’ attitude towards learning programming and robotics and, thus, support students' learning. Teachers expressed their fear of working with content unknown to them, but mentioned that students' motivation inspired them to carry on with the work. García also found that teachers developed pedagogical skills to compensate for the lack of knowledge, focused on guiding students' processes. Another strategy that complements professional development is teachers' cooperation (García, 2018). Since this model depends on the teacher's will, it is unlikely that it will scale up to the system.

In Brazil, a study showed that CS teacher preparation programs emphasized integrating informatics with different disciplines, such as language, arts, mathematics or science, with a focus on software applications (Cruz, 2016). Marqués (2019) showed that most professors who graduated in Brazil could not distinguish between ICT and digital culture. In addition, professional development courses do not reach the large Brazilian territory. Another problem both studies found is the lack of CS educational research and high dropout rates in the first CS courses (mostly in the subject of algorithms), which is common to Argentina's case. Finally, Marques and Cruz point out the gender gap and the lack of motivation to follow a teaching career in CS when the industry offers higher wages.

In Argentina, the Informatics Teachers Association reported that 50% of current informatics teachers do not have preparation for CS, and the other half does not have teacher preparation since their background is in informatics without pedagogy. The Sadosky Foundation program evaluation showed that teacher dropout rates are about 60% and 70%, the same as other programs in CS. It also showed that prior experience in CS does not seem to be relevant to learning CS during the teaching profession. Most teachers attend these courses because they are motivated to raise interest among their students.

In Cuba, most teachers already have a university degree in informatics, but a recent study showed that only a few were enrolled to participate in professional development updates. In general, there is progress in professional development courses, although the scale is small compared to what is needed to supply the system. Taking advantage of the teacher preparation structure already existing in the country to introduce CS seems to be key to addressing this problem.

5.3. Scaling up the program in diverse and fragmented educational systems

Except for Costa Rica, in all the other countries, the scale of CS curriculum introduction in schools is very low. Part of the problem is related to reaching a consensus on the need for teaching CS, which can help a program move forward from a non-state agency initiative to a public educational policy. In most countries, the problem also lies in that CS is not part of the curriculum (in Argentina and Brazil, it is the federal states' decision, in Uruguay and Chile it is voluntary through a pilot, and Cuba and Paraguay are still defining what the curriculum should be). The long experience in Costa Rica can shed some clues on the process: growing gradually with a program that has clear goals, working with universities to offer teacher preparation programs and frequently monitoring and evaluating the program results were key to including a non-state initiative in a public program and to scale up the program.

In addition, the educational systems in Latin America are fragmented, which means that schools are very different and have very different implementation capacities by region, (rural or urban) setting , students' socio-economic level, etc. Thus, one implementation model may not address all the schools' different needs. Following Tapia and Melendez (2021), educational fragmentation involves differential learning circuits for different populations. The research of the last four decades shows that students from different social classes and regions received different types of curriculum and educational opportunities (Tiramonti, 2004). Besides, pedagogical infrastructure, similarly to the school's ability to organize resources, including human resources, is different in school contexts. As a result, learning opportunities are conditioned by social class and region. In addition, a large population in Latin America lives in rural areas. Our participants mentioned that Paraguay and Costa Rica have rural schools and schools serving indigenous populations. Brazil, Argentina and Chile have rural and very distant schools, where internet connection is extremely difficult given each region's geography (mountains and forests). Brazil has a rural population of 27 million inhabitants; Argentina, 3 million; Chile, Cuba and Paraguay, 2 million; Costa Rica, 900 thousand, and Uruguay 100 d thousand. The diverse school composition in the system regarding pedagogical capacity and the region where they are located condition the implementation of any educational program including CS education.

As mentioned in the previous section, a major problem to scale up the program is teachers' preparation. This is a problem not only to implement the program, but also to do it with a certain level of fidelity to the program's objectives. Not requiring a specific degree in CS limits the system's capability to preserve curriculum fidelity. Given the lack of teachers, schools hire teachers with a general knowledge of digital technology. This entry requirements for teaching allows for diversity in what and how CS can be taught.

Finally, not all countries allocate specific budgets for CS education, but use the current structure to develop the CS program. This assumes the system has the ability to develop a curriculum, teaching materials and teacher preparation programs, without being experts in the field. The lack of economic resources to deploy effective policy instruments can hinder the scale of the program.

5.4. Monitoring, following up and evaluating the programs

A structure that can follow up policy mandates is necessary for its effective implementation. Such a structure is in place in many countries, such as Costa Rica, Chile and Uruguay, but not mentioned in the other countries. An Argentinian teacher interviewed specifically mentioned there is no structure to support the implementation of curricular guidelines. A Brazilian teacher interviewed also expressed not knowing how implementation will be supported.

Frequent evaluations seemed relevant to improve the program, make adjustments and show educational gains. Deciding what to evaluate in such diverse countries will be a great challenge.

In addition, mapping the current capacity to train teachers in the regions is vital to public policy planning. With a few exceptions, we could not find data in this study regarding the percentage of teachers holding a CS degree in the job, the number of teacher preparation institutes by region, the number of teacher preparation programs, the number of schools implementing the initiatives, etc. Having this data is relevant to plan and allocate resources effectively.

5.5. Teaching approaches, teaching CS participation and critical perspectives on CS education

Addressing the country's rich diversity and the existing digital divides in these contexts could be an important challenge. Paraguay and Costa Rica mentioned developing a curriculum for their large indigenous population. Currently, as mentioned in the background section, there are CS curriculum developments that include the interests of women and students coming from underserved communities.

Sadosky Foundation in Argentina has also developed a proposal for a CS education curriculum including a critical pedagogy perspective (Martinez, Martinez López, Gómez and Borchardt, Garzón, 2022). An “emancipatory” curriculum in CS education, in addition to traditional CS areas (Programming, Operating Systems and Databases, etc.), includes reflections on the effects of digital technology throughout time, digital identity, information security, ethics of algorithms, legal regulations of algorithms, access to open-sources, operating systems, hardware and general software, participation in open-source communities, managing open-source libraries and regional-based problems with computational solutions. The goal of this curriculum is that students can understand the digital world to participate in it and create from it. One criterion for selecting curriculum content knowledge is Curricula Justice. This means selecting content that provides access to the digital world based on the inequities of the social system. For computer science education purposes, this means offering content knowledge to a population that does not have access to these concepts outside the school, addressing the digital divide and enabling participation.

An emancipatory curriculum in CS also means introducing counter-hegemonic computational practices. In the area of informatics, schools have traditionally introduced computational practices, which are widely known and used in society, such as using private and monopolistic operating systems, accessing computational hardware that has been programmed to become obsolete, using close and private software that cannot be modified, among others. Counter-hegemonic computational practices in computer science include accessing and understanding open-source operating systems that can be run in “older” computers. This not only extends the useful life of computer parts that highly pollute our ecosystems, but it also improves access by sectors that cannot often afford to change computers.

Another important counter-hegemonic practice is accessing open-source libraries, where the CS community shares already-made software, which anyone can use and improve. Accessing these already-existing libraries requires specific CS concepts that relate to basic literacy skills: reading and writing in a particular language (in this case, a language that computers can understand) and, most importantly, understanding grammatical rules and concepts independent of the language syntax.

Counter-hegemonic practices in CS also include working collaboratively at the school and with organizations outside the school to develop computational solutions that can improve the community’s life. These kinds of practices empower children to participate meaningfully in regional problems.

Assigning meaning to CS education so that all students, regardless of their ethnicity, race, gender and socioeconomic status, can access this content to participate critically and actively in the digital world. This is a considerable world challenge considering the particular situation of structural poverty in Latin American countries.

6. Discussion and conclusion

This report describes how seven Latin American countries work to introduce CS content knowledge into their mandatory curriculum. The research shows that all these countries have produced a know-how in terms of policy development and, in some cases, implementation. Collectively, the countries have developed knowledge of defying CS education and developing their curriculum guidelines. In most cases, implementation is steered by non-state actors and supported by external networks. Thus, Latin America has a body of CS education experts locally developed to address its challenges.

Knowledge produced in this report can inform policies from other countries with similar context. In addition, the different programs were analyzed regarding the history of CS education in the country, the structure of the educational system and prior digital infrastructure educational programs. This contextual information will allow policymakers to study and compare their current educational conditions in relation to the policy instruments. Not all policy instruments will be effective in contexts where basic infrastructure and teacher development conditions are not in place.

However, countries with viable contexts can capitalize from the developments of the cases researched: teaching materials in Spanish thought for a Latin American culture, professional development courses for teachers without prior CS content knowledge, teacher preparation programs, etc. In other words, countries starting to develop policies to introduce CS education in Latin America do not need to start from scratch”, but rather ''re-use”, and ''re-mix” policy developments to paraphrase some computational practices from the open software communities.

This work gives rise to new inquiries. One line of questioning is related to the structural educational conditions to be included in CS in the mandatory curriculum. As mentioned earlier, it was difficult to find data regarding teacher capacity in the system, teacher preparation infrastructure, current monitoring of the scope of the program, an estimate of what kind of student benefits from these policies and what kind of student are still left behind in the digital divide. This information is relevant to plan efficiently and to target policy instruments in close articulation with the programs’ goals. A second line of questioning relates to the current program implementation process. Although these works focused on policy instruments, more research is needed to understand how these instruments are working in practice in very diverse Latin American regions. Our educational systems are very fragmented. This means we may have as many educational systems as regions, socioeconomic sectors and culturally diverse communities. We need to understand the value and meaning of CS education in each of these different school systems.

Based on this research, one recommendation for future implementation is to collectively establish clear long-term goals of CS learning. Countries should reach a large consensus on how CS is defined and the implications for this definition for teaching the discipline at schools. With these long-term goals, effective programs have grown gradually and its curriculum and teacher preparation programs have evolved regardless of the changes in governments. Countries' know-how and their developments in defining CS may contribute to other countries' developments. Making alliances with organizations that have spent resources and capacities to think about CS education is key to avoiding starting from scratch. These reports describe many organizations that Latin American countries could reach to capitalize their work.

Along these lines, future work aimed at sharing the information surveyed with participant's countries and —when possible— publish key data to make it available for the rest of the region. Learning from each other's work, successes and challenges are necessary for countries where resources for policy development are scarce. The need to improve the quality of educational systems is urgent to close the sharp digital divide.

ACKNOWLEDGEMENTS

The Sadosky Foundation would like to thank M. Cecilia Martinez, researcher at the Conicet Institute of Humanities and professor at the National University of Córdoba, Hernán Czemerinski, professor at the General Sarmiento University, and Martín Torres, professor at the National University of Cordoba. We thank the Omar Dengo Foundation from Costa Rica, the Plan Ceibal from Uruguay, the Kodea Foundation from Chile, the Paraguay Educa Civil Association from Paraguay, the Universidad del Oriente and the Universidad de Ciencias Informáticas from Cuba, Universidad de Santa Catalina and Centro de Innovación para la Educación Brasileña from Brazil for their contribution to this study, by providing us documentation, introducing us key informants and for their careful reading of our country-case reports.

REFERENCES

Abreu, N. (2021) BNCC: Tudo que vocé precisa saber sobre a Base Nacional Común Curricular

Acilar, A., & Sæbø, Ø. (2021). Towards understanding the gender digital divide: A systematic literature review. *Global Knowledge, Memory and Communication*.

ANEP- Ceibal (2022). Pensamiento Computacional. Propuestas para el aula. Available at https://bit.ly/3QPiLnf

ANEP (2022). Administración Nacional de Educación Pública. Página oficial https://bit.ly/3qIAyBY

Antonio, A., & Tuffley, D. (2014). The gender digital divide in developing countries. *Future Internet*, *6*(4), 673-687.

Bocconi, S., Chioccariello, A., Dettori, G., Ferrari, A., & Engelhardt, K. (2016). Developing computational thinking in compulsory education-Implications for policy and practice (No. JRC104188). Joint Research Centre (Seville site) https://bit.ly/3Dq8XwY

Bordignon, F. R. A. (2018). Saberes digitales en la educación primaria y secundaria de la República Argentina. *ESPIRAL*, *8*(2), 79-90.

Caraballo, S., & Cicala, R. (2005). Hacia una Didáctica de la Informática… *Ponencia presentada en las Primeras Jornadas Nacionales en Didácticas Específicas*. Organizadas por UNSAM

Ceibal, (2019) Marco Referencial de Pensamiento Computacional. Plan Ceibal. Available at https://bit.ly/3QO6MpO

CIEB, 2020. CENTRO DE INOVAÇÃO PARA A EDUCAÇÃO BRASILEIRA. Currículo de referência – Itinerário Formativo em Tecnologia e Computação. São Paulo: CIEB, 2020. E-book em pdf.

Chaves Hidalgo, E., & Berrocal Carvajal, V. (2009). El perfil del graduado en Informática Educativa. Estado de la Educación. CONARE.

Consejo Federal de Educación. Normas sobre Computação na Educação Básica – Complemento à Base Nacional Comum Curricular (BNCC). 17 de Febrero, 2022. Available at https://bit.ly/3BnYak2

Cotik, V., & Monteverde, H. (2016). Evolución de la enseñanza de la informática y las TIC en la Escuela Media en Argentina en los últimos 35 años. *Virtualidad, Educación y Ciencia*, *7*(12), 11-33.

Cruz, M. K., Becker, F., & Hinterholz, L. (2016). Carga Horária Prática na Formação de Professores de Computação e Informática Educativa. In Anais do Workshop de Informática na Escola (Vol. 22, No. 1, p. 698).

Cuadros-Vargas, E., Silva-Sprock, A., Delgado-Castillo, D., Hernández-Bieliukas, Y., & Collazos, C. (2013, October). Evolution of the computing curricula for computer science in Latin America 2013. In 2013 XXXIX Latin American Computing Conference (CLEI) (pp. 1-10). IEEE.

Cuban, L. (1993). Computers meet classroom: Classroom wins. *Teachers college record*, *95*(2), 185-210.

Cuban, L. (2009). *Oversold and underused*. Harvard university press.

Czemerinski, H. and Gómez, M. (2022) Actas de las Primeras Jornadas Argentinas de Didáctica de Ciencias de la Computación : JADiCC 2021 Ciudad Autónoma de Buenos Aires : Fundación Sadosky, 2022.

Del Rey, Angélique (2012): Las competencias en la escuela. Una visión crítica sobre el rendimiento escolar. Buenos Aires. Paidós, pp. 296

Dussel, I. (2020). The Shifting Boundaries of School Subjects in Contemporary Curriculum Reforms. ZEITSCHRIFT FUR PADAGOGIK, 66(5), pp. 666-689.

Echeveste, M. E. and Martinez, M. C. Distribución de tareas en proyectos estudiantiles de computación. *Revista educación y tecnología* 15 (2022): 11-33.

Echeveste, M.E, Gomez, M, Martinez, C y Benotti, L. (2022) La escuela y la brecha de género en la enseñanza de la computación. *En las Jornadas Argentinas de Didácticas de la Computación.* Fundación Sadosky.

Eglash, R., Bennett, A., Cooke, L., Babbitt, W., & Lachney, M. (2021). Counter-hegemonic computing: Toward computer science education for value generation and emancipation. *ACM Transactions on Computing Education (TOCE)*, 21(4):1–30.

Ertmer, P. (2005). «Teacher pedagogical beliefs: The final frontier in our quest for technology integration?» Educational Technology Research and Development, 53 (4), pp. 25-39.

Fonseca, C. (1991). Computadoras en la Escuela Pública Costarricense. La puesta en marcha de una decisión. Serie Educación e Informática 1. Fundación Omar Dengo. Available at https://bit.ly/3xsfnYw

Fundación Omar Dengo. (2007). Alianzas multisectoriales y tecnologías digitales para el desarrollo en América Latina y el Caribe. Estudio de tres casos / Fundación Omar Dengo (Ed.), Fundación Acceso, Fundación ChasquiNet. 1a ed. San José, C.R.: Ediciones Innov@, IDRC. Available at https://bit.ly/3xrIewb

Fundación Omar Dengo (2016). Tecnologías digitales y capacidades para construir el futuro: aportes del Programa Nacional de Informática Educativa MEP-FOD. Fundación Omar Dengo: San José, Costa Rica. https://bit.ly/3ROuFPA

Fundación Omar Dengo. (2018). Trigésimo aniversario del PRONIE MEP FOD evidencia de aportes a la educación y desarrollo del país. Área de Investigación y Evaluación, FOD. Available at https://bit.ly/3LpOcU3

Fundación Omar Dengo (2022). Estrategia de nivelación PRONIE MEP-FOD 2022. https://bit.ly/3DBWhTA https://bit.ly/3QHCDc1

Furber, S. (2012). Shut down or restart? The way forward for computing in UK schools. Technical Report The Royal Society, London.

Fraillon, J., Ainley, J., Schulz, W., Friedman, T., & Duckworth, D. (2020). *Preparing for life in a digital world: IEA International computer and information literacy study 2018 international* report (p. 297). Springer Nature.

Gal-Ezer, J. and Stephenson, C. 2014. A tale of two countries: Successes and challenges in K-12 computer science education in Israel and the United States. ACM Trans. Comput. Educ. 14,

García, J. M. y Castrillejo, D. (2011). Los Robots como excusa. En El modelo CEIBAL. Nuevas tendencias para el aprendizaje (pp. 300-333). Montevideo: ANEP-CEIBAL.

García, J. M. (2018). ¿ Es posible enseñar cuando no se sabe? Estrategias y metodologías utilizadas por docentes en estas situaciones. Tesis de Maestría. Universidad Nacional de Córdoba.

Goode, J. (2010). The digital identity divide: how technology knowledge impacts college students. *New media & society*, *12*(3), 497-513

Gray, T. J., Gainous, J., & Wagner, K. M. (2017). Gender and the digital divide in Latin America. *Social Science Quarterly*, *98*(1), 326-340.

Heintz, F., Mannila, L., & Färnqvist, T. (2016, October). A review of models for introducing computational thinking, computer science and computing in K-12 education. In 2016 IEEE Frontiers in Education conference (FIE) (pp. 1-9). IEEE.

Hernández, A. L., & Cabezas, M. A. C. (2010). Evolución Histórica Del Proceso De Formación De La Cultura Informática Del Profesor De Computación En La Educación Cubana. *Cuadernos de Educación y Desarrollo*, (23).

Ideo Digital: https://bit.ly/3SaHG5A (recuperado en mayo de 2022)

Ithurburu, V. (2019). Estado del Arte. Políticas de TIC y Educación

Ideo Digital (2022) Hacia la Instalación de la enseñanza de las Ciencias de la Computación en el aula: Evaluación de la Implementación Piloto del Modelo de Transferencia de la Iniciativa IdeoDigital (https://bit.ly/3Dv06dp) (recuperado en junio 2022).

Infocomm Media Development Authority. Developing computational thinking and making as a national capability (https://bit.ly/3EyQAob).

Jara, I., Hepp, P., & Rodriguez, J. (2018). Policies and practices for teaching computer science in Latin America. *Microsoft*.

Kafai, Y. B. (2016). From computational thinking to computational participation in K--12 education. *Communications of the ACM*, *59*(8), 26-27.

Ko, A. J., Oleson, A., Ryan, N., Register, Y., Xie, B., Tari, M., Davidson, M., Druga, S. & Loksa, D. (2020). It is time for more critical CS education. *Communications of the ACM*, 63(11):31–33.

Köksaloğlu, C. (2022). *Block-based coding in K-12 education: a systematic literature review* (Doctoral dissertation, Bilkent University).

Koleszar, V., Clavijo, D., Pereiro, E., & Urruticoechea, A. (2021). Análisis preliminares de los resultados del desafío BEBRAS 2020 en Uruguay. *Revista INFAD de Psicología. International Journal of Developmental and Educational Psychology.*, *1*(2), 17-24.}

Koleszar, V., Urruticoechea, A., Oliveri, A., Schunk, M. D. R., & Oyhenard, G. (2022). Scaffolded programming projects to promote computational thinking.

Levis, D. (2007). Enseñar y aprender con informática/Enseñar y aprender informática: Medios informáticos en la escuela argentina. CABELLO, R. y DS LEVIS (comps.)(2007) *Medios informáticos en la educación: a principios del siglo XXI,* Prometeo, Buenos Aires, 21–50.

Macchiarola, V. (2015). Cambios y continuidades en la escuela secundaria: la universidad pública conectando miradas. Estudios evaluativos sobre el Programa Conectar Igualdad Segunda etapa. Available at https://bit.ly/3xs9QBk

Margolis, J., Ryoo, J. J., Sandoval, C. D., Lee, C., Goode, J., & Chapman, G. (2012). Beyond access: Broadening participation in high school computer science. *ACM Inroads*, 3(4):72–78

Margolis, J., Goode, J., & Flapan, J. (2017). A Critical Crossroads for Computer Science for All:“Identifying Talent” or “Building Talent,” and What Difference Does It Make?. In *Moving Students of Color from Consumers to Producers of Technology* (pp. 1-23). IGI Global

Mariscal, J., Mayne, G., Aneja, U., & Sorgner, A. (2019). Bridging the gender digital gap. *Economics*, *13*(1).

Martinez, M. C., & Borchardt, M. (2021) Enfoques y perspectivas didácticas globales en la enseñanza de la computación. SAEI, Simposio Argentino de Educación en Informática

Martínez, C., Martinez Lopez, E, P., Gómez, M. J., Borchardt, M., & Garzón, M. (2022). Hacia un currículum emancipador de las Ciencias de la Computación. Revista Latinoamericana de Economía Y Sociedad Digital, 3. https://doi.org/10.53857/LBUS5649

Marques, S., da Cruz, M. K., & Schulz, F. (2019). Formação Continuada de Licenciados em Computação para Trabalho com Computação na Escola. In Anais dos Workshops do Congresso Brasileiro de Informática na Educação (Vol. 8, No. 1, p. 31).

Ministerio de Educación y Ciencias de Paraguay (2021). Análisis del sistema educativo nacional, diagnóstico para contribuir al debate sobre educación, como parte del proyecto de "Diseño de la estrategia de transformación educativa del Paraguay 2030",

OECD (2017), *Education in Costa Rica*, Reviews of National Policies for Education, OECD Publishing, Paris, https://bit.ly/3Bnli2c.

Oliveira, M.V. (2021) Curriculum de Referencia en tecnologías y computación busca resolver problemas a partir del pensamiento digital. Revista Innovaciones en Educación

Passey, D. (2017). Computer science (CS) in the compulsory education curriculum: Implications for future research. Education and Information Technologies, 22(2), 421-443.

Perez Paredes, P. & Zapata Ros, M. (2018). El pensamiento computacional, análisis de una competencia clave. New York: Createspace Independent Publishing

Romero Moñivas, J. (2013). Del aprendizaje difuso al aprendizaje situacional. Una explicación estructural-conflictiva de las relaciones entre la tecnología y la educación en la sociedad de la información. Revista de Sociología de la Educación-RASE, 6(2), pp. 210-227.

Schleicher, A. (2018). Insights and interpretations. *Pisa 2018*, *10*.

Simari, G. R. (2013). Los fundamentos computacionales como parte de las ciencias básicas en las terminales de la disciplina Informática. In VIII Congreso de Tecnología en Educación y Educación en Tecnología.

Storte, D., Webb, M., Bottino, R. M., Passey, D., Kalas, I., Bescherer, C., ... & Fuschek, G. (2019). Coding, programming and the changing curriculum for computing in schools. UNESCO.

Suarez, D., & Yoguel, G. (2020). Latin American development and the role of technology: an introduction. *Economics of Innovation and New Technology*, *29*(7), 661-669.

Tapia, M. G., & Melendez, C. E. (2021). Análisis y reflexión sobre la fragmentación del sistema educativo en tiempo de pandemia.

Tiramonti, G. (2004). La trama de la desigualdad educativa. Mutaciones recientes en la escuela media Manantial,Manantial, Buenos Aires.

Trucco, D (2013) The digital divide in the Latin American context. In Ragnedda, M., & Muschert, G. W. (2013). *The digital divide*. Florence, KY: Routledge.

UNESCO, 201. The Beijing Consensus on Artificial Intelligence on Education.

Vakil, S. (2018). Ethics, identity, and political vision: Toward a justice-centered approach to equity in computer science education. Harvard Educational Review, 88(1), 26-52.

Vázquez Uscanga, E. A. V., Bottamedi, J., & Brizuela, M. L. (2019). Pensamiento computacional en el aula: el desafío en los sistemas educativos de Latinoamérica. *RIITE Revista Interuniversitaria de Investigación en Tecnología Educativa*.

Vegas, E., & Fowler, B. (2020). What do we know about the expansion of K-12 computer science education. Brookings. Retrieved February, 2, 2021.

Villalba Roberts, M. E. (2018). Efectos de CEIBAL sobre el trabajo docente Análisis del discurso magisterial: de lo local a lo nacional. Tesis de Maestría. Facultad Latinoamericana de Ciencias Sociales Programa Uruguay.

Voogt, J., Fisser, P., Good, J., Mishra, P., & Yadav, A. (2015). Computational thinking in compulsory education:

Towards an agenda for research and practice. Education and Information Technologies, 1-14.

Webb, M., Davis, N., Bell, T., Katz, Y. J., Reynolds, N., Chambers, D. P., & Sysło, M. M. (2017). Computer science in K-12 school curricula of the 2lst century: Why, what and when?. *Education and Information Technologies*, *22*(2), 445-468.

Wilson, C., Sudol, L. A., Stephenson, C., & Stehlik, M. (2010). *Running on empty: The failure to teach k--12 computer science in the digital age*. ACM.

Wing, J. M. (2008). Computational thinking and thinking about computing. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, *366*(1881), 3717-3725.

Zamora, J. C. (2012). Programa Nacional de Informática Educativa (PRONIE-MEP-FOD), Costa Rica. En: Las tecnologías digitales frente a los desafíos de una educación inclusiva en América Latina: algunos casos de buenas prácticas. Santiago: CEPAL, 2012. p. 53-77. LC/L. 3545. Available at https://bit.ly/3QPkIjz

APPENDICES

Appendix 1: Graduation rates by country and income level

Country	Income level	**Year 2015**	**Year 2016**	**Year 2017**	**Year 2018**
Argentina	**30% inferior**	50.1	50.3	52.4	55.3
	30% medium	68.7	66.3	73.1	74
	40% superior	84.4	84.9	84.2	91.7
Brazil	**30% inferior**	48.4	52.4	51.8	53.9
	30% medium	67.9	71.2	72.5	74.8
	40% superior	82.8	87	86.6	89.1
Costa Rica	**30% inferior**	35.6	34.9	35.2	39.7
	30% medium	51.2	57	49.5	55.8
	40% superior	75.5	75.8	76.5	80.9
Chile	**30% inferior**	78.7	-	82.5	-
	30% medium	87.1	-	87.3	-
	40% superior	92.4	-	93.6	-
Paraguay	**30% inferior**	50.8	50.4	51.2	57.2
	30% medium	71.9	67.3	70.2	71.9
	40% superior	84.9	83.6	85.5	86.3
Uruguay	**30% inferior**	20.7	18.5	22.6	23.2
	30% medium	35.9	39.2	44.7	45.8

	40% superior	59.3	64.1	63.5	68

Source: Sistema de Información de Tendencias Educativas en Latinoamérica, UNESCO.

Appendix 2: CS topics addressed by each country

The following table summarizes CS topics addressed in formal schooling by each country. We divide the educational stages into preschool (children from 0 to5 years-old), primary school (from 6 to 11 years-old) and secondary school (from 12 to 17 years-old).

Country	Stage	Algorithms and Programming	Computer Architecture and Hardware	Computer Networks	Security	Data Representation	Data Structures	Artificial Intelligence	Operating Systems	Digital Citizenship
Costa Rica	Preschool [1]	✓	✓	✗	✗	✗	✗	✗	✗	✗
	Primary [1,2]	✓	✓	✗	✗	✗	✗	✗	✗	✗
	Secondary [3,4]	✓	✓	✓	✗	✗	✗	✗	✗	✗
Chile	Preschool	✗	✗	✗	✗	✗	✗	✗	✗	✗
	Primary [5,6,7,8,6,9,10,11]	✓	✗	✓	✓	✓	✗	✗	✗	✓
	Secondary [12,13,14,15,16,17]	✓	✗	✓	✗	✓	✗	✓	✗	✓
Brazil [18]	Preschool	✓	✓	✗	✗	✗	✗	✗	✗	✓
	Primary	✓	✓	✓	✓	✓	✓	✗	✓	✓

	Secondary	✓	✗	✓	✓	✓	✓	✓	✗	✓
	Preschool	✗	✗	✗	✗	✗	✗	✗	✗	✗
Uruguay [19]	**Primary**	✓	✓	✓	✓	✗	✓	✓	✗	✗
	Secondary	✗	✗	✗	✗	✗	✗	✗	✗	✗
	Preschool	✓	✗	✗	✗	✗	✗	✗	✗	✓
Argentina [20]	**Primary**	✓	✓	✓	✗	✗	✗	✗	✗	✓
	Secondary	✓	✓	✓	✗	✗	✗	✓	✗	✓
	Preschool	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cuba	**Primary [21,22,23,24]**	✓	✓	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Secondary [25]	✓	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Paraguay	**Preschool**	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Primary	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

	Secondary	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Appendix 2 references

[1] Fundación Omar Dengo. (2022). Propuesta didáctica LIE++ nivel 1: La programación está presente en el mundo que vivo. Área de Informática Educativa, FOD. (https://tinyurl.com/yvfa4fdp)

[2] Fundación Omar Dengo. (2022). Propuesta didáctica LIE++ nivel 2: Espacios digitales. Área de Informática Educativa, FOD. (https://tinyurl.com/yc6yj9wp)

[3] Fundación Omar Dengo. (2022). Propuesta didáctica LIE++ nivel 3: Conexión entre el mundo físico y las computadoras. Área de Informática Educativa, FOD. (https://tinyurl.com/42bn3m3v)

[4] Fundación Omar Dengo. (2022). Propuesta didáctica LIE++ nivel 4: Espacios creativos utilizando la robótica y la programación. Área de Informática Educativa, FOD. (https://tinyurl.com/pb25n89k)

[5] Desarrollo del Pensamiento Computacional, Fichas pedagógicas para horas de libre disposición, 1ero Básico, Unidad de Currículum y Evaluación, Ministerio de Educación, marzo 2021. (https://tinyurl.com/4cpsm23a)

[6] Fundamentos de Ciencias de la Computación Curso A, Guía Curricular y Planes de Estudio sin Conexión. (https://tinyurl.com/2p8eywsz)

[7] Desarrollo del Pensamiento Computacional, Fichas pedagógicas para horas de libre disposición, 2do Básico, Unidad de Currículum y Evaluación, Ministerio de Educación, marzo 2021. (https://tinyurl.com/yck9j9ky)

[8] Desarrollo del Pensamiento Computacional, Fichas pedagógicas para horas de libre disposición, 3ro Básico, Unidad de Currículum y Evaluación, Ministerio de Educación, marzo 2021. (https://tinyurl.com/tueaee98)

[9] Desarrollo del Pensamiento Computacional, Fichas pedagógicas para horas de libre disposición, 4to Básico, Unidad de Currículum y Evaluación, Ministerio de Educación, marzo 2021. (https://tinyurl.com/yc542fmd)

[10] Desarrollo del Pensamiento Computacional, Fichas pedagógicas para horas de libre disposición, 5to Básico, Unidad de Currículum y Evaluación, Ministerio de Educación, marzo 2021. (https://tinyurl.com/48mpbu74)

[11] Desarrollo del Pensamiento Computacional, Fichas pedagógicas para horas de libre disposición, 6to Básico, Unidad de Currículum y Evaluación, Ministerio de Educación, marzo 2021. (https://tinyurl.com/59dmcvfy)

[12] Aprendo a Programar, Séptimo Básico, Alineado curricularmente con Tecnología Horas de Libre Disposición, IdeoDigital. (https://tinyurl.com/2p9bwzja)

[13] Proyectos prácticos de IA para el aula, una guía para maestros de primaria, Nancye Blair Black and Susan Brooks-Young, ISTE. (https://tinyurl.com/5efbxkc8)

[14] Aprendo a Programar, Séptimo Básico, Alineado curricularmente con Tecnología Horas de Libre Disposición, IdeoDigital. (https://tinyurl.com/yeyua9r9)

[15] Aprendo a Programar, Primero Medio, Alineado curricularmente con Tecnología Horas de Libre Disposición, IdeoDigital. (https://tinyurl.com/2s43bdcu)

[16] Aprendo a Programar, Segundo Medio, Alineado curricularmente con Tecnología Horas de Libre Disposición, IdeoDigital. (https://tinyurl.com/3adt9vx3)

[17] Aprendo a Programar, Tercero y Cuarto Medio, Alineado curricularmente con Tecnología Horas de Libre Disposición, IdeoDigital. (https://tinyurl.com/aeft27bt)

[18] Base Nacional Comun Curricular, Computação Complemento à BNCC, Cristian Brackmann (https://tinyurl.com/33y6cm3d)

[19] Pensamiento Computacional, Propuesta para el Aula, Ana Laura Pérez, Emiliano Pereiro, Graciela Oyhenard, Rosario Schunk, Soledad Yerle, Víctor Koleszar. Ceibal, Pensamiento Computacional. ISBN 978-9974-8700-9-3. (https://tinyurl.com/3cy3p8j6)

[20] Núcleos de Aprendizaje Prioritarios Educación Inicial, Primaria y Secundaria, Educación Digital, Programación y Robótica, Ministerio de Educación, Cultura, Ciencia y Tecnología, 2018. (https://tinyurl.com/bdh25uaz)

[21] Mi mundo digital I, Primer Grado, Hortensia Alfonso Rodriguez, Viviana Guerra Duarte, Santa C. Guzmán Fleites, César Rabañino Rizzo, Yenis Bess Constantén, Carlos Manuel Galán Cordero, Ivonne González Marchante, Marta Smith Martínez. Editorial Pueblo y Educación, 2017. ISBN 978-959-13-3165-6.

[22] Mi mundo digital II, Tercer Grado, Hortensia Alfonso Rodriguez, Viviana Guerra Duarte, César Rabañino Rizzo, Yenis Bess Constantén, Ivonne González Marchante, Leonor Martínez Báez, Zuleima Pérez Hernández. Editorial Pueblo y Educación, 2019. ISBN 978-959-13-3673-6.

[23] Mi mundo digital II, Cuarto Grado, Hortensia Alfonso Rodriguez, Viviana Guerra Duarte, Santa C. Guzmán Fleites, César Rabañino Rizzo, Yenis Bess Constantén, Ivonne González Marchante. Editorial Pueblo y Educación, 2017. ISBN 978-959-13-3276-9.

[24] Mi mundo digital III, Sexto Grado, Hortensia Alfonso Rodriguez, César Rabañino Rizzo, Yenis Bess Constantén, Ivonne González Marchante, Fernando Ortega Cabrera. Editorial Pueblo y Educación, 2019. ISBN 978-959-13-3540-1.

[25] Programa Informática Octavo Grado, César Rabañino Rizzo, María Fuerte González, Armando Abello Aguero, Daynier Rodríguez Faja.