# How Uruguay implemented its computer science education program

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# Summary


Computer science (CS) education helps students acquire skills such as computational thinking, problem-solving, and collaboration. It has been linked with higher rates of college enrollment (Brown & Brown, 2020; Salehi et al., 2020), and a recent randomized control trial showed that lessons in computational thinking improved student response inhibition, planning, and coding skills (Arfé et al., 2020). Since these skills take preeminence in the rapidly changing 21st century, CS education promises to significantly enhance student preparedness for the future of work and active citizenship.

CS education can also reduce skills inequality if education systems make a concerted effort to ensure that all students have equitable access to curricula that provide the needed breadth of skills, regardless of gender, ethnicity, or socioeconomic status.

Based on prior analyses and expert consultations, we selected 11 CS education country, state, and provincial case studies that may have lessons that broadly apply to other education systems. These cases come from diverse global regions and circumstances and have implemented CS education programs for various periods and to different levels of success. As such, we have examined information to extract lessons that can lead to successful implementation.

This study will focus on how Uruguay developed its CS education program. A small country of three and a half million people wedged between Argentina and Brazil, Uruguay has traditionally been known for its herds of livestock and commodity-driven export economy. Yet, attention has been shifting to a “growing constellation” of startups and technology firms that have the potential to turn Uruguay into a regional technology powerhouse (Romero, 2013).


## An overview of CS education in Uruguay

Since 2007, Plan Ceibal—a national education initiative launched by Uruguay President Vazquez—has been distributing digital devices to students and providing schools with internet access, introducing a variety of tools and resources to improve education in Uruguay. Beginning in 2010, Plan Ceibal set up in-school and after-school activities, in coordination with the ANEP[1] (National Administration of Public Education), for students to learn computational thinking, robotics, and coding skills. These efforts have created a culture where teachers and students are encouraged to use technology to explore innovative and practical applications (Zucchetti et al., 2020).

Plan Ceibal has made remarkable progress toward closing the digital divide in Uruguay. It is too early to fully understand its impact since many of its programs are still expanding. Yet, Uruguay has been praised for starting initiatives that foster a culture of innovation that can help the country grow an already prosperous technology industry (Romero, 2013; Serron, 2018; Zucchetti et al., 2020).

## Lessons learned

Examining Uruguay's, progress, four important lessons emerge:

- Uruguay's early emphasis on equitable access to technology has carried over to its approach to CS education. Yet, there is room to make further progress in this area.
- CS activities encourage students to find creative and practical uses of digital technologies that can spark interest in CS, allowing them to deepen their understanding and apply lessons in real-world scenarios.
- In the absence of knowledgeable teachers, Uruguay promoted the use of videoconferencing platforms to improve access to computational thinking lessons.
- Plan Ceibal's initial top-down organizational structure enabled relatively fast implementation of the One Laptop per Child program, whereas closer coordination with educators and education authorities may have helped to better integrate education technology into teaching and learning. More

[1] The ANEP is the state agency responsible for planning, managing, and administering public education in primary and secondary school in Uruguay. It was key in securing school administration approval and integration of computational thinking into teaching-learning practices.

recently, Plan Ceibal has involved teachers and school leaders more closely when introducing CS activities.

For the purposes of this report, we use the term “computer science education” broadly, in the sense that it includes concepts related to computational thinking and robotics that are all closely related to what is traditionally meant by computer science.[2] However, we still treat the subject of computer science distinctly from computer literacy, which refers more to the ability to use applications on a technological device (e.g., word processing or emails).

[2] CS is the study of both computer hardware and software design, including theoretical algorithms, artificial intelligence, and programming (Technopedia).

# Origins and motivation

Plan Ceibal, named after Uruguay's national flowering tree, was introduced in 2007 as a presidential initiative to incorporate technology in education and help close a gaping digital divide in the country. The initiative's main objectives were to promote digital inclusion, graduate employability, a national digital culture, higher-order thinking skills, gender equity, and student motivation (Jara et al., 2018; Presidential decrees April 18th, 2007 and December 15th, 2008). Plan Ceibal started on an ambitious note by distributing a laptop to every public-school student and teacher in the country.

The One Laptop per Child (OLpC) program was rolled out quickly. Nicholas Negroponte, one of the OLpC program's main promoters, commented during Plan Ceibal's 10-year anniversary in 2017: "When I started, there were big countries like Brazil, China, India, that had expressed interest in having OLpC, in doing a very small project. A head of state from one of those countries asked me if I could 'pilot OLpC' in his country. I said to him: 'Do you pilot the electricity in your country?', 'No,' 'But it's the same!' And finally, a small country, yours, came and said: 'We give it to everyone.' And you did it with excellence. You did it much better than any other country" (Álvarez, 2017).

In the first school semester of 2008, Plan Ceibal distributed laptops in the eastern provinces, continued to the west, and then proceeded to the capital, Montevideo, a few months later (Balaguer, 2010; De Melo, 2014). By 2009, every student and teacher in public primary school had her own laptop (Cyranek, 2011). Importantly, the laptops came with Scratch, a digital integrated development environment that offers children basic coding skills. According to Jara et al., (2018), this facilitated a community of users that would set the stage for future CS education.

Beginning in 2010, Plan Ceibal introduced activities to encourage students to learn robotics. These activities began as a pilot project in 10 public schools and gradually expanded to the rest of the country's 2,664 public schools in the next few years. In 2012, Plan Ceibal established the Laboratorios de Tecnologías

Digitales (Digital Technology Laboratories) to promote workspaces dedicated to teaching programming and robotics.

Plan Ceibal extended its robotics education activities by organizing the Robotics Olympics in 2014, which enjoys widespread participation throughout the country. Students are invited to present projects in which they use robotics to solve practical problems. According to Plan Ceibal (2019), "projects involve the identification of a problem, the research process, and the development of an appropriate solution for that problem." At the end of the competition, participants converge to the central activity that takes place over two days in the capital city of Montevideo.

In 2012, Plan Ceibal started using videoconferencing technology to offer instruction in second languages in schools (Stanley, 2015). These courses are delivered to fourth-, fifth-, and sixth-grade students and are taught by a combination of remote specialist teachers over videoconferencing technology and an in-class teacher. The program was first piloted in under 50 classrooms and gradually expanded over the next several years (Stanley, 2015). Currently, about 1,500 schools are equipped with videoconferencing equipment (Zucchetti et al., 2020). This use of remote instruction would later set the stage for a computational thinking curriculum, *Pensamiento Computacional*, which is now delivered in the same format.

The creation of the Ceibal Foundation, which promotes research, innovation, and knowledge building related to technology for education and CS education, as a research center in 2014 was vital to improving Plan Ceibal activities (Zucchetti et al., 2020). The Ceibal Foundation collaborates with Plan Ceibal decisionmakers and partnering organizations while maintaining close contact with relevant policymakers across Latin America. To date, the Foundation has completed 150 publications, implemented 70 projects, and held 60 conferences.

Computational thinking has been adopted as a pedagogical driver to help students develop problem-solving skills. In these classes, a remote instructor introduces computational thinking concepts and in-class teachers facilitate activities, such as block-based programming, that enable students to apply the concepts. This program is still in the process of scaling: In 2018, it reached 580 classrooms, and by 2020, the program had reached 2,051 fourth-, fifth-, and sixth-grade classrooms.

Box 1. A timeline for the development of computer science education in Uruguay

**2007** – President Vázquez initiates Plan Ceibal, which begins to distribute laptops to all students.

**2010** – Robotics education projects begin.

**2011** – Plan Ceibal launches program to train teachers in programming and robotics.

**2012** – English lessons begin via videoconferencing technologies.

**2014** – Robotics Olympics commences through Plan Ceibal. Ceibal Foundation is established as a research center.

**2017** – *Pensamiento Computacional* (Computational Thinking) program begins using the same videoconference technology used for English lessons; Plan Ceibal makerspaces enter secondary schools.

# Institutional arrangements

Plan Ceibal initially featured a top-down organizational structure that enabled quick implementation of its OLpC program. Close coordination among stakeholders has been essential for effective and sustainable administration throughout its ongoing 14-year tenure and has allowed for monitoring, evaluation, and learning (Rivera & Cobo, 2018). This section describes Plan Ceibal's institutional structure, and how it gradually became embedded within the Uruguayan government.

President Tabaré Vázquez initiated Plan Ceibal in 2007 with strong executive leadership, aiming to complete the initial OLpC project before the end of his presidential term in 2009 (Severin, 2016). At the beginning, the president formed a commission consisting of members of his office, the Technological Laboratory of Uruguay (LATU), ANEP, and other government agencies (Vaillant, 2013; Zucchetti et al., 2020; Cobo & Montaldo, 2018). President Vasquez also gave Plan Ceibal, ANEP, and LATU authority and budgetary discretion to streamline decisionmaking and implementation processes (Edelman & Fernández, 2009; Severin, 2016). According to De Melo (2014), these arrangements sped up program implementation, but came at the cost of fluent coordination with teachers, especially in the program's early stages. Indeed, the first three years of Plan Ceibal were primarily focused on deployment of devices, connectivity, and maintenance—all the purview of engineers.

Following the OLpC program, Plan Ceibal enjoyed broad popularity. Yet, the government wanted to strengthen the institutional structure to ensure continuity after the 2009 election (Severin, 2016). In December of 2009, the Uruguayan Senate passed the "Health Promotion and Education in Childhood and Adolescence in the Field of Public Education" law that created the Center for Social Inclusion and Technology (CITS). Due to this legislation, the CITS assumed its own budget and became firmly embedded within the government (Bianchi & Spiller, 2011). A council made up of the president's office, ANEP, the Ministry of Education and Culture, the Ministry of Economy and Finance, the

National Telecommunications Association (ANTEL), and others directed the CITS, which later rebranded itself as the Ceibal Center (Vaillant, 2013).

# Stakeholder engagement

Uruguay has relied on stakeholder partnerships, led mostly by government organizations to achieve its goals. This includes an obvious need for devices, but also for research as Plan Ceibal integrated more CS activities into the standard curriculum.

The government purchases devices from the nonprofit organization OLpC for all students and teachers, while the government-owned company ANTEL connects schools to the internet. Given that most Uruguayan schools lacked CS specialist teachers, ANTEL helped fill this gap by connecting schools with remote instructors who helped teachers in primary school instruction with computational thinking.

As Uruguay's education system began introducing novel concepts like robotics activities to students, it needed to recruit researchers who could provide guidance to Plan Ceibal and its partners. The Ceibal Foundation, as mentioned above, performs this role by analyzing and discussing evidence that supports decisionmaking. The Foundation has identified five specific research priorities (Cobo & Rivera, 2018):

- The use of information and communications technology (ICT) and digital culture, including digital fluency, citizenship, social networks, maturity, and changes in school culture.
- Resources and platforms, including the production and use of educational resources and their usability, inclusion, and accessibility.
- New ways of teaching, learning, and assessing knowledge using new technologies and pedagogies.
- Evaluating learning progress in formal and informal learning activities.

- Teaching in the digital age, including basic training and the use of technology.

To make progress in these research priorities, the Ceibal Foundation participates in the Global Learning Network's New Pedagogies for Deep Learning (Cobo & Rivera, 2018). The Network promotes information exchanges among teachers and policymakers in 10 countries about ideas, experiences, and pedagogical innovations. The New Pedagogies project specifically focuses on 21st century skills like collaboration, creativity, and communication. By participating, Uruguay aims to learn from other countries and incorporate innovations into Plan Ceibal activities.

# Teacher preparedness and training

A dearth of qualified CS teachers has been and continues to be a challenge for Uruguay. Though Plan Ceibal runs online and in-person teacher training activities, the effectiveness of some of these activities warrants further evaluation (García, 2020). Plan Ceibal's and the ANEP's efforts to address the challenge of having qualified CS teachers include connecting remote technology professionals to coordinate with the in-class teacher and provide lessons to students via videoconference. This section documents the various efforts Uruguay has undertaken to train teachers in CS subject matter and pedagogy.

Since the 2007 rollout of the OLpC program, Plan Ceibal has facilitated professional learning communities for teachers to learn subject matter and pedagogies through peer-to-peer learning (Cobo & Rivera, 2018). The objective of these communities is to guide in-person instructors on technical matters and address the specific needs of each school. Plan Ceibal also provides resources that promote the continuous training of teachers and networking and collaboration opportunities among educators who are interested in computational thinking (Cobo & Rivera, 2018).

Years before official computational thinking instruction was introduced in schools, a survey found that 41 percent of teachers felt they had at least adequate knowledge of programming skills (Friss & Fonseca, 2013). The survey also indicated that teachers had underutilized helpful tools for learning to code. Twenty percent of teachers had previously used Scratch in their instruction. Fifty percent of teachers knew about Scratch but had not used it, while 30 percent did not know what it was.

In 2011, Plan Ceibal launched a program to train 1,600 secondary school computing teachers and primary school teachers in programming and robotics (Friss & Fonseca, 2013). The training consisted of three modules, each 12 hours in duration: (1) programming using Scratch, (2) basic robotics programming, and (3) robotics projects. By 2018, over 28,000 teachers had enrolled in Plan Ceibal teacher training courses in educational technologies (Cobo & Montaldo, 2018). Plan Ceibal also has an online training program for in-school and remote teachers that provides in-person and online training in digital pedagogies including a comprehensive course in key computational thinking concepts and robotics, as well as coding in Scratch and Python (Cobo & Rivera, 2018).

In 2020, the ANEP conducted another survey of computational thinking competencies among in-class teachers involved in computational thinking programs: A third of respondents said that they had never received any training. Surprisingly, surveyors observed few competency differences between those who received training and those who did not (García, 2020). This would suggest that either there was significant learning that occurred initially among teachers when the OLpC program and Scratch were distributed or that the additional training was ineffective.

# Plan Ceibal CS education activities

Uruguay's CS activities are grounded in evidence that effective learning results from active construction of contextualized knowledge rather than reliance on classroom lecture or independent reading (Zucchetti et al., 2020; Cobo & Montaldo, 2018). The cross-curriculum integration emphasizes computational thinking and programming that all teachers must address in their activities while supporting other disciplines (Jara et al., 2018). Additionally, Uruguayan schools feature innovative concepts like robotics competitions and makerspaces that allow students to creatively apply their computational thinking lessons and that can spark interest and deepen understanding. Plan Ceibal provides resources to implement these activities at the request of the schools and students, unlike the OLpC program that distributed laptops to every student and teacher regardless of learning preferences.

Computational thinking has been integrated across subject areas (e.g., biology, math, and statistics) (Vázquez et al., 2019). In this manner, Plan Ceibal fosters interdisciplinary projects that immerse students in imaginative challenges that foster creative, challenging, and active learning (Cobo & Montaldo, 2018). For example, students can use sensors and program circuit boards to measure their own progress in physical education (e.g., measuring how many laps they could run in a given time).

As part of the *Pensamiento Computacional* program in 2017, Plan Ceibal began providing remote instruction in computational thinking lessons for public school fifth- and sixth-graders (Plan Ceibal Website), and integrated fourth-grade a year later. Classrooms work on thematic projects anchored in a curricular context where instructors integrate tools like Scratch.[3] During the school year, a group of students can work on three to four projects during a weekly 45-minute videoconference with a remote instructor and another group can work on projects for the same duration led by the classroom teacher. In a typical week,

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[3] In 2019, President Tabaré Vázquez stated that "All children in kindergartens and schools are programming in Scratch, or designing strategies based on problem solving" (Uruguay Presidency, 2019).

the remote teacher introduces an aspect of computational thinking. The in-class teacher then facilitates activities like block-based programming, circuit board examination, or other exercises prescribed by the remote teacher (Cobo & Montaldo, 2018).[4] Importantly, Plan Ceibal implements *Pensamiento Computacional*, providing a remote instructor and videoconferencing devices at the request of schools, rather than imposing the curriculum on all classrooms (García, 2020).

This expansion of CS education also involves secondary school education. In 2017, Plan Ceibal piloted a computational thinking initiative for secondary schools as a cross-curricular subject. The project—titled Ceilab—involves setting up spaces in schools filled with technological resources where teachers can get support from a facilitating teacher to develop projects. Each Ceilab includes a cart with 30 devices (15 laptops and 15 tablets) and a mobile trunk with robotics kits, sensors, and other materials (e.g., control devices, fabrics, sticks, and glue) as requested by each school (Jara et al., 2018).

Bridging the gap between formal in-school education and extracurricular after-school activities, Plan Ceibal runs the Robotics Olympics that involve multi-grade and multi-disciplinary events for secondary school students. Participating students converge at the Robotics Olympics that take place annually over two days in Montevideo. In the competition, students are given kits that they can use to build robots, which they also program to perform given tasks. For example, students in rural Tacuarembo won the top prize in 2017 for their project that recycled gray water for agricultural purposes (Cobo & Montaldo, 2018). More than 1,800 students and 450 teachers participated in the 2019 competition (García, 2020).

In addition to K-12 activities, Plan Ceibal began a Youth Program (targeting youth aged 18-30) in 2017 to teach programming language and computational thinking and has since benefitted 1,400 students. One of its activities, "*A Programar*" (to program), gives students the opportunity to use online courses to practice basic coding skills (de Kereki & Manataki, 2016; de Kereki, et al, 2018). The Youth

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[4] Remote instruction via videoconferencing technology has been shown to improve learning in mathematics in an experiment in Ghana (Johnston & Ksoll, 2017). It is very plausible that Uruguay's approach to giving computational thinking instruction via videoconference could also be effective.

Program provides reading materials and workshops consisting of both online and in-person courses. Participants also get opportunities to visit potential job sites and do practice job interviews (Apella et al., 2020).

# Inclusion

Despite success in making access to digital devices and the internet more inclusive, girls and rural students have fewer opportunities to develop an interest in CS (Lacnic News, 2019; Tomassini & Urqhuart, 2011; Zucchetti et al., 2020). Continued rollout of CS activities over time, however, could give more women, girls, and rural students a chance to develop an interest and pursue future jobs in the technology industry.

Plan Ceibal has made efforts to bridge urban-rural inequalities from the beginning when it prioritized distributing laptops to students in rural areas before Montevideo (Balaguer, 2010; De Melo, 2014). The government even put solar panels on the few schools that had not been connected to the electrical grid so they could have better access to education technologies (Fullan et al., 2013). In 2006, the share of population that had a digital device in the home was less than 6 percent in the first income quintile, and almost 49 percent in the fifth quintile. By 2010, those figures rose to 60 and 65 percent, respectively. When Plan Ceibal implemented the OLpC program, the country achieved near universal access for students and teachers in preschool and secondary schools. To further improve digital equity, Plan Ceibal also concentrated on Wi-Fi connectivity, and today roughly 2,500 of country's 2,664 public schools have connectivity.

Although access to laptops is universal, elements of CS education have yet to reach every school. To date, 1,500 schools have been equipped with videoconferencing equipment that are concentrated in urban schools (Zucchetti et al., 2020; García, 2020), leaving about 1,000 mostly rural schools without the technology. Since this videoconference hardware is necessary to offer computational thinking lessons in schools, access to *Pensamiento Computacional* is still limited in rural areas. However, Plan Ceibal is in the process of distributing the hardware throughout the country, so more students may soon have better access in all regions of the country.

Disparities also exist between genders, as fewer Uruguayan women than men develop an interest in CS. According to Andrea Delgado, CS professor at the University of the Republic of Uruguay,[5] the proportion of women who choose technology jobs is comparatively lower than that of social sciences, medicine, or humanities. In 2019, women represented only 15 percent of students enrolled in CS in her university, even though generally more women than men enroll in the university (Lacnic News, 2019). To help remedy this imbalance, Delgado and colleagues introduced the Promoting Careers in ICT Among Teenagers in Uruguay project to attract a greater number of girls to CS through after-school activities. Plan Ceibal's Youth Program has also taken steps to raise interest in CS among young women. Supported by the Uruguayan Chamber of Information Technologies, Plan Ceibal introduced a women-only cohort in 2019 to learn CS concepts (Apella et al. 2020), which attracted 700 participants in the first year.

# Conclusion

For more than a decade, Uruguay has made significant investments in promoting access to computers and CS in schools. Serron (2018) describes Uruguay as the "Silicon Valley of South America" for several reasons, including how Plan Ceibal is making a new generation of workers more comfortable with technologies. Indeed, the demand for CS professionals appears to be higher in Uruguay than in neighboring countries (Apella et al., 2020; Romero, 2013), indicating a high degree of foreign investment and/or domestic entrepreneurship. This trend suggests that there may have been some success at fostering a "computing culture" within the country.

Plan Ceibal's focus on inclusiveness from the beginning of the program carries over to its more recent CS activities. Uruguay provides an example of a country that faces many difficulties and still prioritizes giving rural students a chance to develop an interest in CS. It also has a unique approach to providing quality instruction by directly connecting students that would otherwise be difficult to reach to CS instructors through video conferencing technology. Even if the remote instruction proves effective, however, just like other countries, Uruguay's

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[5]The University of the Republic of Uruguay is by far the country's oldest and largest university.

education system still faces the challenge of extending computational thinking lessons to every primary school and training teachers to integrate computational thinking as a cross-curricular topic.

Plan Ceibal's early focus on technology use shifted to a student- and teacher-centered pedagogical approach. Students not only learn how to use digital technologies, but also how to design them for practical use. The Uruguayan education system does this by integrating computational thinking as a cross-curricular subject and a standalone class so that students can learn key skills at an early age and then apply them in Ceilabs, the in-school creative spaces for student-led projects, and other courses as they move into secondary school. While the OLpC program distributed laptops to students and teachers in the first few years, Plan Ceibal now designs and implements CS activities in coordination with teachers and at the request of schools.

The Ceibal Foundation and the New Pedagogies for Deep Learning project bolster Plan Ceibal's effort to research and improve its programs. Uruguay uses rigorous evaluations that inform decisionmaking, which will help improve instruction over the long term. In turn, this approach should give the country a greater opportunity to train a generation of problem-solvers and technology professionals for the future.

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