How Italy implemented its computer science education program

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Summary

Computer science (CS) education helps students acquire skills such as computational thinking (CT), problem-solving, and collaboration, among others. It has been linked with higher rates of college enrollment (Brown & Brown, 2020; Salehi et al., 2020), and a recent randomized control trial study also showed that lessons in CT improved student response inhibition, planning, and coding skills (Arfé et., 2020). As these skills take pre-eminence 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 them with the needed breadth of skills, regardless of their gender, ethnicity, or socioeconomic status.

Based on prior analysis and expert consultation, we selected 11 country, state, and provincial CS education case studies from which we can draw lessons that may apply broadly 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.

A relatively wealthy country and member of the G8 economic group, Italy seeks to maintain a competitive edge by preparing for economic transition despite a large portion of its workforce being vulnerable to widespread automation. Given these trends, CS education has the potential to play a powerful role in helping Italy's next generation develop valuable twenty-first century skills. This study will examine how Italy is expanding these learning opportunities.

For this case study, we define CS as the study of both computer hardware and software design (Technopedia, n.d.). CS education can also include elements of CT: a problem-solving approach that involves decomposition, use of algorithms, abstraction, and automation (Wing, 2006). The term "informatics" typically refers to the study of hardware and software, CT, and digital literacy. In the Italian K-12

education system, however, informatics tends to apply more narrowly to denote the use of computers and digital literacy (Belletini, Lonati, Malchiodi, Monga, Morpungo, Torelli, and Zecca, 2014).

An overview of CS education in Italy

Italy's approach to CS education is still emerging, and at present only provides systematic CS learning opportunities to students late in the course of K-12 matriculation. The Ministry of Education has favored programs that encourage students to become interested in CS as many schools have participated in "Programma il Futuro," a nation-wide project focusing on principles of CS. At the upper secondary school level, students have options to take CS-specific courses if they choose to specialize in science (rather than the arts). At this level, CS teachers have been trained with rigorous preparatory coursework, increasing the likelihood of delivering a high-quality CS education.

Yet, elements of CS are rarely featured in primary and lower-secondary schools.[1] Most teachers are untrained to teach CS having never studied the subject themselves in school (Lodi, 2020). The Ministry of Education has not yet started to change the curriculum or implement teacher training to meaningfully bring CS into these grade levels. Additional curricular requirements are needed for earlier grade levels to motivate more students to take an interest in CS and prepare Italy's future workforce for an increasingly digital global economy.

[1] Within the subject Technology, which covers all technological disciplines, there is only an indication that students should reach the goals of being able to install and use apps, explore how apps work, and—if possible--develop simple programs.

Lessons learned

- Too much flexibility in the curriculum can allow some teachers to focus on the least challenging aspects of a technology course. This has permitted many teachers in Italy to focus on information communication technology (ICT) education instead of CS and CT.
- Upgrading teacher qualification is the most important action that Italy can take to scale up CS education.
- Nonprofit organizations play a role in introducing students to the subject, but in-class curricular reform is needed to introduce CS in primary schools.
- Even if students can learn CS in technical and preparatory schools at the upper-secondary level, a lack of exposure in early grades can limit student interest in the subject once they reach later grades.

Origins and motivations

Italy faces a unique set of opportunities and challenges for the digital age. On one hand, it has a dynamic network of start-up businesses and a highly competitive ICT ecosystem that contribute to a complex economy. On the other hand, it has a traditional primary school curriculum that leaves little space for computing activity (Corradini, Lodi, Nardelli, 2017). Italy also faces significant labor market challenges that may stifle future growth. The country ranks third in Europe for the most workers who are underqualified for their jobs. Further, only 20 percent (half the OECD average) of adults participate in job-related training. Given these challenges, there is a clear rationale for policymakers to bring CS education into Italian schools.

To engage students and enhance teacher qualification, a national consortium of universities in informatics collaborated with the Italian Ministry of Education in 2014 to launch "Programma il Futuro" (Program the Future). Organizers initially translated the Hour of Code materials into Italian while maintaining 'scientific precision' in the descriptions of relevant concepts (Corradini, Lodi, Nardelli, 2017). The initiative expanded quickly in the first two months after its launch, reaching over 7,000 registered teachers and over 18,000 student participants in at least one coding event (Nardelli & Ventre, 2015). Since the program began, Programma il Futuro has helped three million students learn the basics of CS since it features not only programming activities but also an introduction to algorithms, abstraction, and the internet. It also offers teaching guides for developing awareness in students about the use of Information Technology and social networks (Corradini & Nardelli, 2018; Corradini & Nardelli, 2020; Corradini & Nardelli, 2021). Today, the program features a network of more than 35,000 teachers (at least one present in 90 percent of Italian schools).

In 2016 the Ministry of Education launched the Digital School National Plan ("La Buona Scuola") that envisioned CT in primary schools for 10 hours per year

(Ministero dell'Università e della Ricerca, n.d.). However, the central government never implemented primary school CT education on a national level, even if individual teachers integrated CT into their lesson plans. Thus, the broader education system would have to implement more ambitious measures to teach students the discipline of CS, even though most of them have had an introduction through Programma il Futuro.

In 2018, the European Commission issued the Digital Education Action Plan that enumerated key digital skills for European citizens and students, including CS and CT. The plan encouraged young Europeans to understand the algorithms that underpin the technologies they use on a regular basis. In response to the plan, Italy's 2018 National Indications and New Scenarios report included a discussion on the importance of CT and the potential role of educational gaming and robotics in enhancing learning outcomes (Comitato Scientifico Nazionale per le Indicazioni Nazionali, 2017). However, the definition of CT in this report was unsatisfactory as implementers and policymakers debated the role of CT as a stand-alone school subject (Nardelli,2019).

In 2019, the Italian Ministry of Education and the Parliament approved a legislative motion to include CS and CT in primary school curricula by 2022 (Orizzontescuola, 2019). Valentina Aprea, one of the motion's main proponents, said that "artificial intelligence, robotics and biotechnology are the new fields to be developed to foster a new era of work, to improve rather than replace the conditions and opportunities of work. For this reason, programming must be considered as the fourth basic skill for the new generations of students, together with reading, writing, and arithmetic (Orizzontescuola, 2019)." The government clarified that this legislative motion would not include the introduction of a new subject in primary or middle school, leaving unclear how political declarations could be implemented in concrete actions in school. Indeed, the ministry has not yet included CS in primary and lower-secondary school curricula.

Course development and curriculum

With the support of Italian community of academic researchers in Informatics education in December 2017, the National Laboratory on Informatics and School prepared a proposal for an Informatics curriculum covering the 10 years of compulsory school education (Forlizzi et al., 2018). The proposal has been discussed in a public event at the Italian Chamber of Deputy the same month (Programa il Futuro, 2017), but no concrete decision regarding curricula has been taken since then.

Italian middle schools do not offer CS courses. Instead, they offer two hours of Technology where students learn the skills and knowledge about contemporary society and ICT (Belletini et al., 2014; Giaffredo, Mich, & Ronchetti, 2018). While the Technology curriculum does not require instruction in CS, some schools have experimented with learning frameworks such as agile software development to integrate CT into the broader curriculum. However, according to Lodi (2020), schools and teachers take advantage of the flexibility to teach the less challenging aspects of what can be taught in an Informatics curriculum. As a result, teachers often focus on use of ICT instead of instruction in CT and CS.

At the same time, upper-secondary school students have opportunities to specialize in academic disciplines and learn CS lessons that are tailored to their interests. Italian high schools, including Lyceums (preparatory high schools), technical schools, and professional schools, integrate CS instruction to varying degrees based on standards listed by the Ministry of Education. Roughly half of upper-secondary students go to a Lyceum while the other half is split between professional and technical schools. Lyceums focus on general education with room for specialization by offering CS courses for students that follow some of the specialized scientific tracks. Technical schools also offer a specific CS curriculum in their technology programs, with courses such as Technology of Informatics, Systems and Networks, and Technology and System Design. In their first year of technical school, students can take Technology of CS, where they learn concepts such as codification, computer architecture, problem solving, and internet networking (Belletini et al., 2014).

Overall, the Ministry of Education structures its courses so that students attending secondary technical schools can specialize in their future careers while already in secondary school, even without attending post-secondary educational institutions. However, a lack of exposure to CS in primary school years limits interest in the subject amongst the general student population even with availability of technical education in upper-secondary school.

Teacher preparedness and professional development

Schools and teachers mostly focus on the use of computer programs rather than creative problem solving and CT (Belletini, et al., 2014). According to Giaffredo et al. (2018), teachers often lack the commitment to learning CS because competency standards are unclear and the approach is optional.

To teach informatics in an upper-secondary school, however, teachers must have a master's degree in a relevant subject (e.g. CS, information engineering, physics, or mathematics) and participate in a competitive exam (Belletini et al., 2014; Lodi, 2020). This is necessary since upper-secondary schools must offer more specialized subjects.

Most teachers still hold misconceptions of CS as too few receive appropriate training (Corradini, Lodi, & Nardelli, 2017 August; Corradini, Lodi, & Nardelli, 2018). Further, teachers of STEM (science, technology, engineering, mathematics) subjects are not required to have a formal technical education. Consequently, most informatics teachers in middle school are unqualified to teach the subject. As a result, most students receive limited instruction in CS, as classroom activities mostly revolve around the use of software, typically Microsoft Office (Belletini et al., 2014; Lodi, 2020).

Inclusion

Like many other education systems, Italy has underserved populations of students who may not have opportunities to develop an interest in CS. This section describes how the Ministry of Education and various stakeholder partners are trying to address this challenge.

Low CS enrollment rates for women at Italian universities reflect the gender gap in CS education. As of 2017, 12.3 percent of students completing bachelor's degrees in CS were women (Marzolla, 2019). Further, female professors and researchers in these two subjects are also underrepresented. In 2018, only 15 percent and 24 percent of professors and researchers in CS and Computer Engineering, respectively, were women (Marzolla, 2019). To make CS education more gender balanced, the Ministry of Education and partner organizations have implemented programs to get more girls interested in the subject so that they can later specialize in CS (European Commission, 2009). For example, an Italian employment agency (ironically named Men at Work) launched a project called Girls Code it Better to extend CS learning opportunities to 1,413 middle school girls across 53 schools in 2019. During the academic year, the girls attended extracurricular CS courses before developing their own technologically advanced products and showcasing their work at an event at Bocconi University in Milan (Brogi, 2019). In addition to introducing the participants to CS, the initiative provided the girls with role models and generated awareness on the gender gap in CS education in Italy. These programs may be an effective strategy to making CS higher education and professional opportunities more gender balanced. A wide study done within Programma il Futuro showed that involving girls early is an effective way to increase their interest and effectiveness in CS activities (Nardelli & Corradini, 2019).

Civil society stakeholders have also extended CS learning opportunities to refugees and asylum seekers. Over 60,000 unaccompanied refugees, 90 percent of whom are age 15 to 17, arrived in Italy between 2014 and 2018. Due to the refugee influx, European organizations began to explore the role of CS education in integrating refugees and providing them with valuable programming skills through interactive activities (Kuhl & Lehner, 2016). In 2019, the non-profit organization Code Your Future and LVenture Group hosted a free six-month coding program in Rome for refugees, asylum seekers, and low-income Italian citizens.

Conclusion

CS instruction has yet to be fully deployed into the Italian education system, due to the lack of curricular reform and appropriate teacher education. In the meantime, CS is gaining momentum among some Italian schools as they participate in initiatives such as Programma il Futuro which invites teachers to attend Code.org's Hour of Code and European Union's CodeWeek. Further, an understanding of CS can have broad professional and civic benefits to students and their communities even though a small portion of students specialize in CS at the university or professional levels. Therefore, it is important for Italy to expand its offer of CS instruction to primary and lower-secondary schools.

Providing more training and professional development (PD) resources to pre-service and in-service teachers will be essential to providing quality instruction. Pre-service teachers benefit from learning and applying core CS skills in classrooms during training and will facilitate the Ministry of Education's push towards CS instruction if they receive enough PD opportunities.

To fully realize the benefits of CS education, Italian schools will need to address gender inequality in the education system and facilitate learning opportunities for disadvantaged groups. Stakeholders in academia and industry are taking initial steps by introducing CS to girls and refugees by organizing training sessions, competitions, and other events.

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