Computational Thinking in Italian Schools: Quantitative Data and Teachers' Sentiment Analysis after Two Years of "Programma il Futuro" Project

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ABSTRACT

In this paper the first two years of activities of "Programma il Futuro" project are described. Its goal is to disseminate among teachers in Italian primary and secondary schools a better awareness of informatics as the scientific basis of digital technologies. The project has adapted Code.org learning material and has introduced it to Italian schools with the support of a dedicated web site. Response has been enthusiastic in terms of participation: in two years more than one million students have been engaged and have completed a total of 10 million hours of informatics in schools. Almost all students found the material useful and were interested, teachers have reported. They have also declared to have experienced high satisfaction and a low level of difficulty. A detailed analysis of quantitative and qualitative data about the project is presented and areas for improvement are identified. One of the most interesting observations appears to corroborate the hypothesis that an exposure to informatics since the early age is important to attract students independently from their gender.

KEYWORDS

Computational thinking; Informatics education; Experience report

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1 INTRODUCTION

Digital technology pervades all aspects of human life and is based on an independent and recognized science: informatics ("computer science" in USA, "computing" in UK). Moreover, concepts and practices of informatics are used by researchers in a lot of fields, from other sciences to humanities. This approach to understand the world and solve complex problems is called *computational thinking* [11]: thinking like a computer scientist to solve problems. In the last decade, the awareness that computational thinking is a valuable skill for every human being has increased, and the introduction of informatics as a standard school subject is more and more discussed.

At school one learns Physics, Biology, History, Literature not (necessarily) to become a scientist, a writer, and so on, but to understand the world one lives in. Finding out what's behind technologies allows students to become informed citizens, and to better debate and decide on crucial issues like genetics, privacy, e-vote and so on. Moreover, a lot of the so-called "digital jobs" are unfilled because of the lack of prepared workforce. To cover this vacancy, a broad education in computing is mandatory. More specifically, to increase the number of students (and in particular underrepresented categories such as women) who choose to graduate in Computing disciplines, an early exposition during K-12 to the basis of informatics is required so as they can fully understand and - if the case - appreciate it.

Informatics is a powerful way to describe and comprehend the world: Denning and Rosenbloom have coined the expression "the fourth great domain", putting computing on par with physical, life, and social sciences as a way to grasp what is so about the world [1]. It is also a good learning tool: to "teach" the computer how to solve a problem, you have to fully understand problem domain, issues and strategies to solve it. Knuth wrote "*It has often been said that a person does not really understand something until he can teach it to someone else. Actually, a person does not really understand something until he can teach it to a computer*" [5]. Moreover, informatics offers a constructive strategy for problem solving.

Currently, the most widespread methodology to teach computational thinking is teaching to program, often with languages and environments suitable for learner's age and experience (for example, for young children and beginners, environments where instruction are not textual code but visual elements that must be combined together to create a videogame or an animation). Another widespread methodology involves the so called *unplugged activities* (the most famous is New Zealand CS Unplugged[1]) where students are taught computer science concepts like algorithms, information encoding, cryptography and so on through traditional games that don't need technology but material like pen and paper or simply student's own bodies. Particularly interesting for computational thinking are games where one child embodies the programmer and another one the programmed agent. Lastly, the use of educational robots that must be programmed is also dramatically increasing.

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[1] http://csunplugged.org/

In recent years, no-profit organizations, volunteer movements and also private initiatives aiming at spreading computational thinking to young people flourished. Most of them are of high quality and have helped to gain institutions and media attention on computational thinking. But they can't afford to provide informatics education to all: K-12 public educational system has to take in charge this ambitious target.

Having recognized the importance of a broad informatics education [3], many countries are making efforts to introduce it at all school levels. Some example are United States [4], United Kingdom [10], France [2] and many other countries.

In Italy, the Ministry of University, Education and Research (MIUR) and the National Interuniversity Consortium for Informatics (CINI – a consortium made up of all Italian research universities active in Informatics) agreed, in March 2014, to launch the three-years project "*Programma il Futuro*" ("Program the Future") [7] to change the way informatics is taught in Italian schools. The objective to introduce computational thinking in primary and secondary school is explicitly stated in the school reform approved by the Italian Parliament in 2015 [8] whose operational plan for what concerns digital technology is defined in the subsequent Italian National Plan for Digital Education (Piano Nazionale Scuola Digitale — PNSD): "a policy launched [...] for setting up a comprehensive innovation strategy across Italy's school system and bringing it into the digital age"[2]. It was therefore important to stress that all digital technologies are rooted in a scientific discipline, informatics, independent from other sciences. "Programma il Futuro" was set up mainly to address this goal and to bring teachers and students closer to the fundamental concepts of informatics.

The project "Programma il Futuro" is explored in detail in Section 3. It is based on materials from Code.org organization, which is briefly outlined in Section 2.

2 CODE.ORG

Unlike UK, where computer science is a mandatory subject for all primary and secondary schools, until 2013 very few USA states had computer science in school curricula, in spite of being probably the most advanced country in IT technology. To counter this situation, the no-profit organization Code.org[3] launched in the same year the "Hour of Code" project, with the initial goal of having each student in the world do at least one hour of programming and, in perspective, the final goal of having for each student a proper education in computer science.

Code.org developed teaching material made up of online interactive web tutorials, featuring famous video games and cartoons characters, highly attractive for students. To define a program you have to combine visual blocks, based on Blockly library[4], much like it happens in Scratch [6] and in other visual programming environments. But differently from Scratch, where a student is exposed since the beginning to the entire set of instructions and has complete freedom in the artifact to realize, here the student is given specific tasks. The initial exercises are very trivial (e.g. have a bird move straight of 3 steps) and the set of available instructions is very small (e.g. "move forward", "turn left/right"). Then, the difficulty degree increases very slowly from one exercise to the next, and instructions and programming structures are progressively added to the set. If the student is not able to successfully complete an exercise, the system provides some feedback, useful for self-correction. Students are thus increasingly exposed to the basic concepts of informatics (gradually introduced while reinforcing the previous ones) without being distracted by technical or syntactical details. A teacher is therefore able to follow her students during these tutorials with little specific training in informatics. Moreover, since students may have their own accounts to execute activities, they are able to learn keeping the pace better matching their needs.

Web tutorial are interspersed with *unplugged* activities that teach or reinforce important informatics concepts. Printable material and a detailed lesson plans are provided.

Teaching material and curriculum progression have been defined keeping in mind the K-12 Computer Science Framework[5], developed by ACM, CSTA, CIC, NMSI and Code.org itself.

Code.org tries to provide the first elements of a basic education in computer science to all students while an adequate number of teachers trained in that topic is not available. Its action addresses every classroom in a school, every children – both males and females – regardless their ability, family means or cognitive status.

Code.org had, in its first school-year alone, more than 40 million students doing their first hour of coding all around the world, and each year the participation doubled.

3 THE "PROGRAMMA IL FUTURO" PROJECT

3.1 The Project

The project "Programma il Futuro" (PIF, from now on) has a lifespan of three school-years, starting from 2014-15.

The initiative has been framed and presented in term of learning *computational thinking* as a key competence for modern education, so as to stress the importance of the cultural value of informatics more than its technical and technological aspects. Bear in mind that before this initiative, informatics teaching in primary school in Italy was mainly based on learning how to use word processors and spreadsheets.

PIF project is based on the teaching material developed by Code.org, described in Section 2. All Italian teachers are invited at the beginning of each school-year to use it in their classes, at least for one hour. Participation is optional and any teacher is encouraged to do the experience, whichever is her own teaching subject. This approach was chosen due to its scalability characteristics. By leveraging on-site teachers and well suited online teaching material it is possible to faster bring to action a much larger number of students.

In perspective, the project aims to facilitate the establishment of an adequate informatics education in all school levels in Italy.

While targeting primarily teachers and students, initiative has also addressed adult population, according to the principle that education in fundamental concepts in informatics has both an intrinsic intellectual value and a practical role in understanding the IT basis of today's societal mechanisms. The project material is used also in adults' training centres, out-of-school education initiatives and for self-learning, even by the elderlies.

[2]http://www.istruzione.it/scuola_digitale/allegati/2016/pnsd_en.pdf
[3]https://code.org/
[4]https://developers.google.com/blockly/
[5]https://k12cs.org/

3.2 Material

PIF translated the textual material of all the tutorials (both online exercises and unplugged activities), paying particular attention to scientific precision and consistency.

PIF implemented a support website[6] referred to by the Italian subdomain of Code.org[7] to allow teachers building an Italian community of users. Following a carefully designed communication plan and an iterated development approach, the site provides a comprehensive guide for teachers.

There are six main sections in the website: *Il progetto* ("The project"), with a general description of the project, of its background and motivations, of its theoretical foundations; *Chi* ("Who"), with specific information for the participation of different kind of users (teachers, students, others); *Percorsi* ("Paths"), with a description of available courses and teaching materials; *La comunità* ("The Community"), where users can find useful information to connect each others and share experiences; *Notizie* ("News") where press material and news about institutional events related to the project is collected; *Aiuto* ("Help") where users can ask for technical or educational support, interact in a forum, find tips to guide an activity with students.

In particular, in the *Percorsi* section, for each course and lesson of the courses proposed by Code.org a detailed webpage (in Italian) explains concepts taught in that lesson and its general and specific learning objectives. Additionally, for each lesson, a video tutorial in Italian has been realized to provide a step-by-step guidance to any user towards a successful completion of the activities. All video tutorials and other communication material is available on the project's YouTube channel.

The forum is structured in a set of threads, some of general nature (e.g., how to manage a class), others focused on the various available courses.

Teachers have the possibility of organizing, through the website, local meetings to discuss among themselves problems and solutions to teach informatics to students.

3.3 Organization

PIF operations are entirely supported by a set of companies financing it with different amounts of money and providing also volunteers that donate part of their working time to help schools in moving the first steps in a territory which is new and unknown for many of their teachers.

MIUR has given its endorsement to the project and at the beginning of each school-year officially invites all schools to participate by sending them a ministerial circular. This has been essential for a country where school organization and curricula are defined mostly at the state level.

Also important has been the constant support of a bipartisan group of Members of the Italian Parliament (Intergruppo Innovazione – Intergroup for Innovation), some of whom have even recorded a video where they code together with kids.

[6]http://www.programmailfuturo.it/
[7]https://italia.code.org/

In 2016, the project has been recognized as a European outstanding initiative for digital education and awarded with one of the European Digital Skills Awards[8].

Many communication events have been held during the life of the project, which have been essential to increase its knowledge among teachers and parents. A prestigious one has been the opening of the second year, held at the Italian Chamber of Deputies, hosting as special guest Hadi Partovi, CEO and founder of Code.org. Moreover, since the beginning of the third school-year PIF has won the support of an international basketball star, Marco Belinelli, playing in NBA.

The project constantly interacts with end users through its social channelsand teachers can report and publish their first-hand experiences related to coding in theirs classes.

4 PARTICIPATION DATA

Since the first year (school-year 2014-15), Italian teachers have been highly reactive to the initiative, making Italy the most active non-english speaking country for what regards informatics education in school, at least in terms of participation to the CSEd week[9].At the end of school-year 2015-16 about 14,000 teachers in more than 4,000 schools had involved more than 1 million students (about one eighth of Italian students) in the activities. Project participation has tripled from the first to the second school-year and a similar trend for the current school-year is expected.

Considering both the two school-years, students have collectively done about 10 million hours of coding. In particular, during school-year 2014-15 students worked for a total of 1,657,101 hours (avg 5.4 hours per student), while during the next year (2015-16) students worked for 8,654,100 hours (8.5 per student), a more than five-fold increase.

Details of participation are described by the four charts in Figure 1, showing trends for schools, teachers, classes, and students.

5 PROJECT MONITORING

5.1 Data Collection

The project monitors progresses two times a year through a questionnaire sent to all teachers, first in December, right after the CSEd week, and then in May, a few weeks before the end of school year[10].

The questionnaire collects descriptive data about teachers and their classes/schools, quantitative data about students participation to coding activities, and qualitative feedback. A few optional questions are open and are intended to investigate both positive and negative sentiments of teachers with respect to the project.

The percentage of answers received has always been high (15% to 17% for 2014-15; 21% to 24% for 2015-16; number of recipients for each of the four questionnaires is shown in graph "teachers" in figure 1), providing a good confidence that values and comments received are reasonably representative of the situation of the entire population.

[8]https://ec.europa.eu/digital-single-market/en/news/16-outstanding-projects-european-digital-skills-award-2016-final
[9]https://hourofcode.com
[10]http://programmailfuturo.it/progetto/monitoraggio-del-progetto

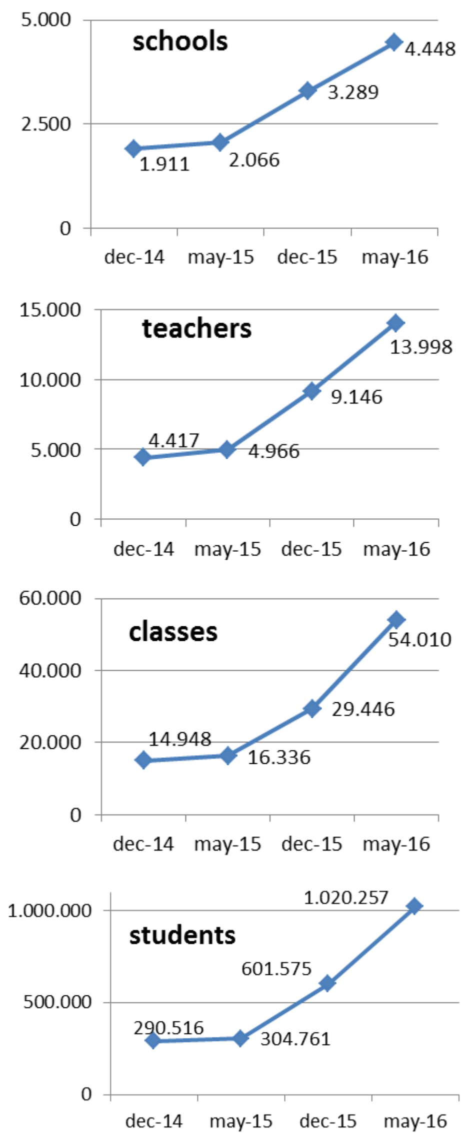

Figure 1: Students, teachers, classes and students participation.

5.2 Quantitative Data Analysis

In school-year 2015-16, more than half of teachers was in primary school, and almost a third in lower secondary (see Fig. 2) while in the previous year there was a higher percentage of primary school teachers (56%) at the expense of lower secondary one (27%).

It is interesting to observe the different distribution of subjects taught by the teachers involved in the project according to the different level of school. Subjects have been classified in two large groups: literary and scientific/technical, while informatics has been considered on its own. Please note that both in primary and lower secondary school generally informatics is not an independent subject. The distribution (shown in the two charts in Fig. 3) does not significantly change between the two school-years. It is a highly

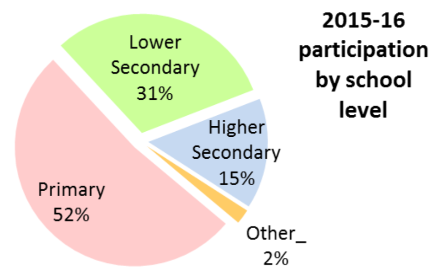

Figure 2: Participation by school level.

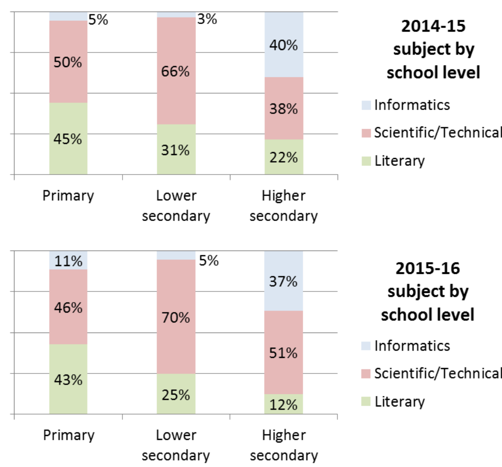

Figure 3: Teachers' subject distribution by school level.

positive element the fact that also teachers of literary subjects have involved themselves in bringing computational thinking to the attention of their students.

It was asked to teachers to evaluate how useful was the activity for their students on a 4-point Likert scale: 98% of them answered "useful" or "very useful". It was also asked them to evaluate how interested were their students during activities: 98% of them answered "interested" or "very interested". These outcomes are essentially the same in the two school-years.

Teachers were asked to evaluate whether in their classes students were equally interested by the activities irrespective of their gender, or females/males were more interested. Results, shown in the chart in Fig. 4, are similar across the two school-years and exhibit an increasing polarization when students grow up.

Similarly, teachers were asked to evaluate effectiveness of students in executing activities with respect to their gender. Also in this case the results, shown in the chart in Fig. 5, are similar across the two school-years: the older the students are, the higher is the polarization.

We think both results, hinting that informatics acceptance has a higher independence from gender when pupils are younger, provide some support for the importance of exposing students to it at an early age.

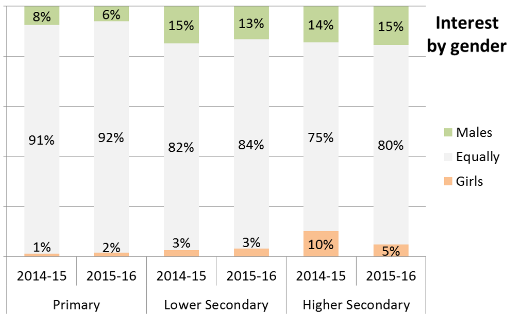

Figure 4: Interest by gender.

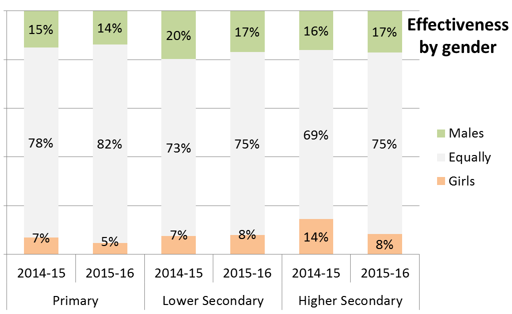

Figure 5: Effectiveness by gender.

5.3 Qualitative Data Analysis

We now discuss the sentiment analysis regarding teachers' answers to open questions.

Positive sentiments were explored by two open questions: "Describe the most positive factors in the project" and "Provide a reason to suggest participation to a colleague". A total of 1,342 (resp. 1,313) answers, across the two school-years, have been provided to the first (resp. second) question.

In a first phase, all answers were processed by the authors and divided if they contained more than one concept. We thus obtained a total of 1,523 (resp. 1,551) single concept sentences. All sentences were analysed again by the authors to identify recurring themes, that were found to be common to both groups of answers. These became the clusters used to classify sentences. Finally, each single concept sentence was manually assigned to one of the clusters. Here is the short name and description of the most relevant ones:

- *Cognitive stimulation and cognitive development* (promotion of awareness and comprehension of: computational thinking, problem solving, logical thinking, creativity, attention, planning ability, . . .)
- *Motivation and participation* (motivation for learning, students interest, students and teachers involvement, cooperation between students)
- *Methodological aspects* (effective outcomes, ludic learning, innovative approach for teaching informatics, inclusive didactics)
- *Quality of instructional material* (well prepared, attractive, structured for gradual learning)

Table 1: Cluster distribution of positive sentiment answers

	Positive factors	Reasons to suggest
Cognitive	20%	26%
Motivation	32%	26%
Methodological	20%	26%
Quality	18%	9%

In both groups (see Table 1) *Motivation and participation* is the most frequent cluster, while also *Cognitive stimulation and cognitive development* and *Methodological aspects* play an important role. Cluster *Quality of instructional material* is perceived more as a "positive factor" then as a "reason to suggest", which is a viewpoint coherent with teachers' pedagogical perspective.

Other interesting answers by teachers, not included in the most relevant clusters, warrant deeper consideration and analysis in further works. For example, some teachers stressed the positive consequences in terms of attention improvement for students with concentration difficulties.

Negative sentiments were first explored by means of a follow-up open question to a yes/no question: "Have you experienced difficulties?". Furthermore, a yes/partly/no question: "Has the project matched your expectations?" is followed with an open question asking for clarifications, in case of partly or total mismatch. A total of 334 (resp. 275) answers, across the two school-years, have been provided to the first (resp. second) question.

The lower number of answers to these questions (roughly speaking, the total number of negative remarks is about one quarter of the total number of positive ones) is a clear indication of the general satisfaction of teachers with project activities. Indeed, 91% of teachers did not report any difficulty during school-year 2015-16 (it was 88% in 2014-15), and 84% of teachers were fully satisfied in 2015-16 (82% in 2014-15).

A first analysis of answers to the two open questions investigating negative sentiments showed that the kind of remarks were similar. It was therefore decided to merge the two sets and carry out a cluster analysis on the whole set, using the same methodological approach used for positive sentiment analysis. Multiple concept answers were simplified in 786 single concept sentences, that were manually partitioned in disjoint clusters.

We now list the most relevant topics resulting from this analysis, with a short name, a description and its ratio in the overall distribution:

- *Technical problems* (34%) (Obsolete or too few devices, absent or very slow Internet connection, . . .)
- *Teacher training* (18%) (Lack of personal knowledge to solve the exercises or to prepare an adequate lesson plan with specific computational thinking learning objectives, too little time to self-train, absence of specific training courses, difficulties with English-written material, . . .)
- *Organizational and logistic problems* (16%) (Mainly lack of time to teach the material during lessons due to an already crowded school schedule)

All these clusters point to infrastructural problems, that are independent from scientific issues concerning informatics education.

Other clusters, with a lower ratio, can provide useful hints for actions aiming at introducing informatics education at all school levels in Italy. In particular we found other four main topics:

- *Limitations of platform and support site* (11%) (Both technical problems or lack of features of Code.org and problems with the support site, sometimes stated as not clear or too verbose)
- *Quality/level of teaching material* (10%) (Material too easy or too difficult - and so not engaging - for the specific age level of the students)
- *Curriculum and didactics* (6%) (Teaching effects not clear or visible, difficulties in integration with standard curriculum, lack of creativity in activities - often compared to Scratch)
- *Colleagues/parents involvement and support* (5%) (Lack of support from colleagues during the activities or from parents at home)

Issues related to *Curriculum and didactics* are the most relevant ones to move from a stimulus action phase to a full operational one.

A final open optional question asked for "Observations and suggestions": most of its answers have been positive, stressing the importance of computational thinking education in Italian schools and showing willingness to continue activities, even proceeding in autonomy. The main request for improvement has been to provide the italian dubbing of videos accompanying the courses.

We finally provide a few literal quotations from teachers, highlighting some of the discussed positive outcomes:

- *"The ludic nature of activities has been able to create unexpected interest and motivation in students"*
- *"Students have been able to better understand what computers can do: there is more in information technology beyond game consoles"*
- *"I have observed improvement in observation and reflection skills: students have been able to find alternative solutions"*
- *"Students felt themselves in the spotlight of activities and were gratified by the immediate feedback"*
- *"Parents have appreciated the possibility of continuing activities at home"*

6 CONCLUSIONS AND FUTURE PERSPECTIVES

Outcomes of project monitoring show that informatics education is a highly interesting theme for both teachers and students and that in a short time span the proposed teaching material has been adopted, used, and appreciated in a significant number of classes. We therefore think that appropriateness of teaching material is a key factor to bring informatics education in schools.

Hence the project is on track to meet the goal of spreading among school teachers more awareness of the principles, concepts and methods of informatics.

Concerning competence acquisition by students, we do not have a formal measure of their progresses in the project, since the Code.org material does not include a set of assessment tools. Clearly, since learning material is partitioned into very small chunks and later exercises require having learned previous concepts and skills, progressing in courses is a good proxy indication of actual competence acquisition. How to carry out in schools the measurement of the acquisition of the various informatics competences is an open problem, to be tackled by joint efforts by computer scientists and pedagogists.

Another important issue, raised by some teachers, is how to merge the "closed" teaching paths provided by Code.org material with the need of providing more "open" venues, where both teachers and students are able to give space to their creativity. This issue, and the more general one whether it is better a "puzzle based" or a "project based" approach to informatics education, is also highly debated in the research community [9].

Finally, two issues of systemic and institutional nature are informatics curricula for different school levels and teachers training. They are clearly intertwined, since for each school level teachers have to be prepared to teach what students should learn at that level. Computer scientists can cooperate toward this goal, but the final responsibility is under the power of governmental institutions.

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