Informatics Education in School: A Multi-Year Large-Scale Study on Female Participation and Teachers' Beliefs

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Abstract. This paper describes the outcomes of a multi-year large-scale study on Informatics education in school, involving an average of 3,600 teachers per school year of all school levels. The study has been conducted in Italy, where - generally speaking - there is no compulsory informatics education in school. Teachers have voluntarily enrolled in the "Programma il Futuro" project, running since 2014, and have taught short introductory courses in Informatics. Answering - anonymously - to monitoring questionnaires, they have indicated whether girls or boys were more interested in Informatics activities and whether girls or boys were more effective.

Answers show that the difference between the number of teachers thinking boys are more interested (or more effective) and the number of those judging girls more interested (or more effective) has constantly decreased over school years during the project. This variation in teachers' beliefs over school years - that we attribute to their involvement in project activities - is important, since teachers' beliefs are known to influence students' motivations, hence their future choices. Our opinion is reinforced by the results of a differential analysis, in each school year, between teachers repeating activities and those executing them for the first time.

Moreover, the analysis of disaggregated data shows that the difference between boys and girls relative to interest or effectiveness increases going up in school level. Our results provide an empirical support to the belief that it is important to start Informatics education early in school, before gender stereotypes consolidate.

Keywords: Informatics education in school · Broadening participation · Gender and diversity

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1 Introduction

Many developed countries declare a shortage of workers well trained for computing related jobs [11,16]. This has become even more important in recent years, given that computing occupations are a larger and larger share of jobs [8].

Moreover, the existing information technology workforce does not adequately represent the diversity of society [10,21,38], largely due to the fact that too few girls and minorities enroll in computing related discipline [9,26,40].

The introduction of compulsory Informatics[1] education in schools and its extension to all school levels has been proposed as one possible measure to change this situation [6]. The rationale is that, by gaining since school a better comprehension of the real nature of the discipline, students - and girls in particular - can be more inclined to choose it for their university studies [28,39].

Related to this, it is also debated at which level of schools Informatics education should be introduced (see [15] and [42] for an in depth discussion), since some consider it an advanced discipline requiring students are mature enough to grasp it well. On the other side, there are some highly reputed learned societies who see it as fundamental as mathematics, hence advocate its introduction since the first years of school [1,37]. This is what happened, for example, in UK, where a computing curriculum became mandatory in 2014 for all levels of school.

In our study we investigated school teachers' beliefs in Italy regarding the interest and effectiveness of girls and boys towards Informatics. We think this is an important factor to increase female participation in the CS field, since teachers' beliefs are known to affect students' motivations, hence to influence their future choices of the university degree course to attend.

In this paper "kindergarten" indicates the pre-school level, for students up to 5 years old; "primary" indicates the 5 first years of school, attended by students aged between 6 and 10 (roughly, both endpoints included); "lower secondary" indicates the 3 years of intermediate studies, attended between 11 and 13; finally, "higher secondary" indicates the 5 last years of school, between 14 and 18. We always use these labels with the above described meaning, since this is their standard meaning in Italy.

2 Related Work

The introduction of Informatics education in school levels earlier than the higher secondary one is largely debated issue [3,15,42]. Even a country like, e.g. Poland, which has some form of compulsory Informatics education in higher secondary schools since the 80s, has not had compulsory Informatics education for primary school until a few years ago [35]. Duncan et al. [15] discuss that the best age for students to learn programming depends on many factors (cultural, environmental, social, personal, and instrumental) and should be considered in a multi-disciplinary context (e.g., psychology, pedagogy, mathematics, and language). In any case, they conclude "*it is clear from a variety of evidence that*

[1] We use interchangeably the terms Informatics and Computer Science (CS).

some exposure to programming before about 12 years old is both worthwhile and feasible". Also Armoni and Gal-Ezer [3] agree this issue is a complex one and "*cannot be addressed without deep and thorough research*".

It is also important to consider that the choice of the subject a student will study at the university and/or will do as a job is affected by many factors, beyond the actual age of her exposition to the subject during school years. Research has highlighted that students' motivation is affected by individual factors, situational ones, and how these interact [31,32]. Many studies support the conviction that teachers' beliefs affect student's motivation [5,20,22]. For a successful Informatics education uptake in K-12 it is therefore important to understand the actual teachers' viewpoint.

Moreover, social aspects cannot be neglected. In fact, negative stereotypes about girl's STEM abilities are transmitted to them by their teachers, shaping their attitudes and undermining their performance and interest [19,34].

In addition, it is known that well-designed educational programs can increase the participation of women to CS in college [17,23]. Research has highlighted the importance of acting at K-12 level, where girls risk to be discouraged and to lose interest in STEM careers [25], also under the influence of the stereotype seeing a CS student as a socially awkward and technology focused male [7, 26] and of social and cultural biases [10]. Moreover, role-model in K-12 is an important element [33], given its positive influence on girls' confidence when they are subject to negative stereotypes [27]. Finally, school performance in early STEM courses influences future students' choice of a major in the field [29].

By comparing female increasing participation efforts in computing to those in other disciplines, Zagami et al. [44] argue that the presence of a compulsory CS curriculum since early level of school might be the only measure able to sustain female participation over periods such as adolescence, a stage where students start making critical career choices [43]. The importance of acting since primary schools on the improvement of CS image so as to fight misconceptions and stereotypes and to increase female participation in computing has also been discussed in [18].

3 Methods

3.1 Context

Our analysis has been done in the context of Italian "*Programma il Futuro*" project[2] (PiF, from now on) for Informatics education in schools: it is a countrywide initiative which has been running since school year 2014–15 [12–14]. Italy does not generally have in place compulsory CS teaching in school, but for some types of upper secondary school. In the past, Informatics education has largely been focused on the operational aspects of using digital tools, like in many other developed ones [41]. Therefore, while it is under debate the possibility of introducing some form of compulsory Informatics education in schools, voluntary initiatives have flourished.

[2] https://programmailfuturo.it.

PiF's activities are grounded on both visual programming computer-based exercises *à la* Scratch (accompanied by video tutorials and automatically evaluated by the web platform supporting the project) and unplugged exercises on CS fundamental principles in the style of CS Unplugged (for which detailed lesson plans are made available). The teaching material is made available by Code.org and fully adapted to Italian by our team.

3.2 Questionnaires

Teachers involved in PiF are more than 33,000 at the beginning of school year 2018–19 (the fifth for the project). They voluntarily enroll, are generally not trained in CS, and usually teach a number of different subjects. A continuous communication action is deployed to keep them active and motivated.

Teachers are asked to fill out monitoring questionnaires with demographic and participation data. During each of the school years 2015–16 and 2016–17 they answered to two questionnaires (after three months and at the end) while in 2017–18 only one (the first one).

The goal of PiF is to spread information and awareness about the scientific nature of Informatics and not to investigate differences between boys and girls in attitude or performances related to Informatics. Nevertheless two questions in these surveys consider the possible imbalance between girls and boys in interest and effectiveness while carrying out the activities:

Q1 *In your classes, students* ***more interested*** *to project activities have been...*
Q2 *In your classes, students* ***more effective*** *in executing project activities have been...*

For both questions only one of the following answers can be chosen (they are presented to teachers in random order):

- equally students of both sexes
- female students more than male ones
- male students more than female ones

Note that activities carried out in classes are the same for both male students and female ones and are not elective, hence were attended by all female and male students. Note also that during the first year of PiF (2014–15) these two questions were not present in the pilot version of the monitoring questionnaire.

We are aware a better approach to the research question "At which school level is it better to introduce informatics education so as to reduce the gender gap?" would have been based on the measurement of the actual attitude or performance of students. However, considering the wide spectrum of school levels and the high number of project participants, it would have been a hugely complex task.

3.3 Population and Sample Demographics

We provide here some demographic data, during the analyzed school years, regarding both the *population* of teachers enrolled into PiF and the *sample* who

Table 1. Teachers' sex distribution

	2015–16		2016–17		2017–18	
	pop.	sam.	pop.	sam.	pop.	sam.
female	11,552	3,050	22,869	3,936	28,576	2,017
male	2,740	704	4,365	707	5,135	405

Table 2. Teachers' age distribution

	2015–16		2016–17		2017–18	
	pop.	sam.	pop.	sam.	pop.	sam.
to 30	89	*	191	31	214	13
31–40	1,617	*	2,853	487	3,154	204
41–50	5,547	*	10,217	1,924	12,033	906
51–60	5,782	*	11,140	1,930	14,096	1,112
61 up	1,257	*	2,833	271	4,214	187

* = this school year age was not asked

answered to the monitoring questionnaires. For those school years in which two monitoring questionnaires were issued, data from the second one reported here comes only from those teachers who did not answer the first one.

Table 1 shows how teachers are distributed according to their sex. In each school year the sample is a significant representation of the population with respect to sex, given that the average value[3] of the sum of the squared differences (ASSD) between values in the sample and their expected values[4] is less than 1.1% of the sample size in each school year. The percentage of women in the population (from 81% to 85%) is very close the actual percentage of female teachers in Italy (81%).

Table 2 shows how teachers are distributed according to their age. In each school year the sample is a significant representation of the population, with an ASSD value (computed as above) always less than 1.4%.

Table 3 shows how teachers are distributed according to the level of classes they teach in. In each school year the sample is a significant representation of the population also with respect to the school level, given the ASSD value (computed as above) is, again, always less than 1.4%.

A few teachers in each school year preferred not to declare the level of classes they teach in, hence the totals for the samples in Table 3 slightly differ from the corresponding ones in Tables 1 and 2, without prejudice for the analysis.

Monitoring questionnaires from school year 2016–17 onwards also investigated teachers' job seniority, a datum that is not collected when they enroll into PiF. Table 4 shows how they are distributed according to their teaching seniority in years. For both school years the sample is made for more than 84% by experienced teachers, which is a positive element in terms of the reliability of their answers.

[3] Computed as $\frac{\sqrt{\Sigma_i (s_i - e_i)^2}}{N}$, where s_i is the actual value for the i-th class in the sample, e_i is the expected value (see next footnote) for the i-th class in the sample, and N is the number of classes.

[4] Expectation is computed as $S \cdot p_i$, where S is the size of the sample and p_i is the percentage of the i-th class in the population.

Table 3. Teachers' school level distribution

	2015–16		2016–17		2017–18	
	popul.	sample	popul.	sample	popul.	sample
Kindergarten	433	55	1,391	183	1,992	73
Primary	7,799	1,969	14,822	2,606	18,262	1,431
Lower Secondary	3,911	1,149	7,155	1,252	8,586	626
Higher Secondary	2,248	555	3,866	590	4,511	287

Table 4. Teachers' seniority distribution

Years	2016–17	2017–18
up to 2	94	24
3 to 5	154	102
6 to 10	465	193
More than 10	3,930	2,103

Table 5. Classes and students involved

	2015–16	2016–17	2017–18
Classes	14,532	14,871	8,362
Students	272,529	297,272	153,697

We also asked teachers to report the overall number of classes they involved in Informatics education activities of PiF and how many students there were in their classes (see Table 5). We did not ask them the distribution per sex of their students but we consider that the study is based on a reliable sample of Italy's students also with respect to their sex, given (i) education is mandatory in Italy up to 16 years of age, (ii) teachers enrolled in PiF belong to all regions of Italy, and (iii) the very large number of students involved.

4 Results and Discussion

We do not discuss kindergarten data given these teachers are less than 4% of the sample size in each school year. Remember also that, for those school years in which two monitoring questionnaires were issued, data from the second one reported here comes only from those teachers who did not answer the first one. In the following subsections we first report results aggregated by school year (Subsect. 4.1.1), then results of the differential analysis (Subsect. 4.1.2) for each school year between teachers repeating activities and those executing them for the first time, and finally results aggregated by school level (Subsect. 4.1.3).

4.1 Aggregated Data

4.1.1 Results for School Years

Table 6 shows teachers answers to Q1 and Q2 in each school *year*. To make sense out of these data we computed for each year an indicator, the **interest gender gap**, that we defined as the difference, in that school *year*, between the number of teachers who rated male students more interested to project activities than female ones and the number of those who rated female more interested than boys (rows labeled respectively "M" and "F" in Table 6 and subsequent ones). We analogously computed the indicator **effectiveness gender gap**. To make these two indicators comparable across school years we normalized them, by computing their ratio to the total number of teachers who answered in each school *year*, and we present them in Fig. 1 as value per thousand teachers. As you can see both indicators are decreasing as the school years pass, roughly in the same constant way from a school year to the next.

Table 6. Answers to Q1 and Q2 for school years

	Q1 - Interest			Q2 - Effectiveness		
	2015–16	2016–17	2017–18	2015–16	2016–17	2017–18
Equally students of both sexes	3,223	3,987	2,133	2,885	3,639	1,976
Female students more	98	113	60	229	266	133
Male students more	352	348	151	559	543	235

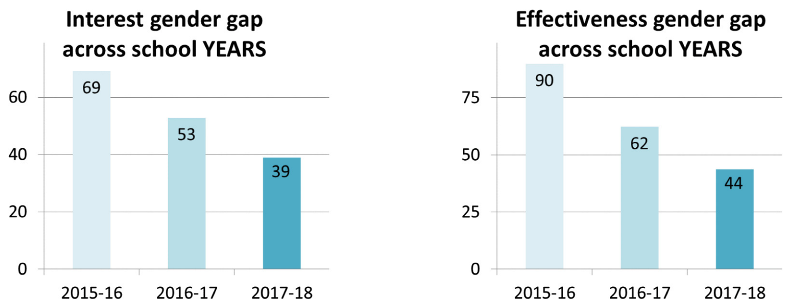

Fig. 1. Gap indicators across school YEARS (values per thousand teachers)

It is a widespread stereotype that female students' performances in science and maths are worse than their male companions' ones [7,10,25,27]. We do not know how much this stereotype was spread in our population before the beginning of PiF, but Fig. 1 shows the existence of a lower incidence of this stereotype with the progress of project activities over the years.

We hypothesize the involvement of teachers in project activities is the primary factor causing the observed variation of indicators. We think the observed phenomenon is relevant, since teachers answered anonymously to surveys, a condition that more likely can lead people to provide answers expressing a biased position [24,30]. We hence presume people answered honestly to our questionnaires. Moreover, if some remaining unconscious pressure not to express one's own gender bias had remained, its effect would only have reduced the size of the two gender gap indicators. Finally, even if in Table 6 the share[5] of teachers

[5] Computed as $\frac{F+M}{E+F+M}$.

having reported a difference between male and female students is just around 10% (for Q1-Interest) and 18% (for Q2-Effectiveness) of the total, we think that (i) given the overall number of answers this is a phenomenon which cannot be ignored, and (ii) given the above discussion of uneasiness in declaring a biased position the phenomenon's size might be even larger.

4.1.2 Novice and Repeating Teachers

To better understand the significance of the observed phenomenon we also investigated whether teachers executing PiF activities for the first time (*novice*) and those who were involved in previous years (*repeating*) had different beliefs. More specifically, we re-computed the two gender gap indicators shown in Fig. 1 separately for novice and repeating teachers for each of the school years 2015–16 (77% of novice), 2016–17 (52%) and 2017–18 (20%). Remember PiF started in 2014–15.

As you can see in Fig. 2, for each school years both indicators have a lower value for repeating teachers than for novice ones. In other words, in each school year, repeating teachers consistently show a lower presence of the stereotype that female students' performances in science and maths are worse than their male companions' ones. In our view, this result confirms and strengthens the observation made in Subsect. 4.1.1 of a lower incidence of the stereotype with the progress of project activities.

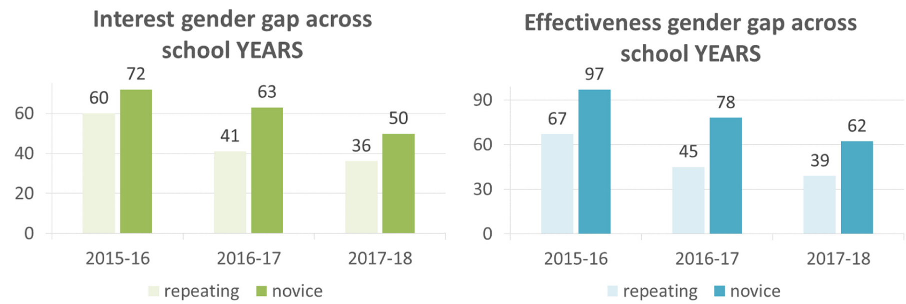

Fig. 2. Differential analysis of gap indicators across school YEARS

Note that the figure shows that the falling trends of the two indicators is present also for novice teachers who, by definition, cannot have been affected by the repetition of the activities. To understand this we have to consider that the increase in schools participation over the years is lower than the increase in teachers participation. The yearly increase in the number of participating teachers has been of 85% in 2016–17 and of 22% in 2017–18, while for schools it has been of 32% and 9% respectively.

This means that, roughly, for each new school entering PiF (clearly with a new teacher) there have been in the average almost two teachers entering the project in schools where their colleagues were already involved[6]. Therefore, a large part of novice is made up by teachers who have entered PiF because of their colleagues. Considering this element together with the concept of stereotypes as social and cognitive activity [4,36], a possible motivation is that beliefs of novice teachers have been affected by repeating teachers lowering their bias over the years.

4.1.3 Results for School Levels

Table 7 shows teachers' answers to Q1 and Q2 in each school *level*.

We computed again the two normalized indicators above described, this time on the basis of the difference, for each school *level*, between the number of teachers who rated male students more interested to project activities than female ones and the number of those who rated girls more effective than boys. Normalization was done with respect to the total number of teachers who answered in each school *level*. The indicators, shown in Fig. 3, are again presented as values for thousand teachers. As you can see both indicators are increasing going up with school level. This shows the existence of a higher presence, going up with school levels, of the stereotype considering girls worse than boys in science.

Table 7. Answers to Q1 and Q2 for school levels

	Q1 - Interest			Q2 - Effectiveness		
	Primary	**L**ower Secondary	**H**igher Secondary	**P**rimary	**L**ower Secondary	**H**igher Secondary
E	5,606	2,596	1,137	5,603	2,353	1,084
F	99	93	79	296	232	100
M	301	338	212	647	442	248

Different approaches could be followed to fight this stereotype and possibly many of them need to be integrated to be effective. The starting point is to sensitize teachers in order to make them aware of the risks ensuing from the stereotype. In addition, given the social and cognitive nature of the stereotype, an early start of Informatics education in school would contribute to improve the attitude of teachers and students towards CS. Our result therefore provides an empirical support to those who advocate to start Informatics education in schools since the early years in order to fight this stereotype.

Moreover, note in Fig. 3 the big jump of the interest gender gap from Primary to Lower Secondary. While it is often said that middle school is the play-field where to win girls' interest to CS [2], we think this jump shows, instead, that Informatics education needs to start in Primary.

[6] The average number of teachers per school was 3.15 in school year 2015–16 and 4.95 in 2017–18.

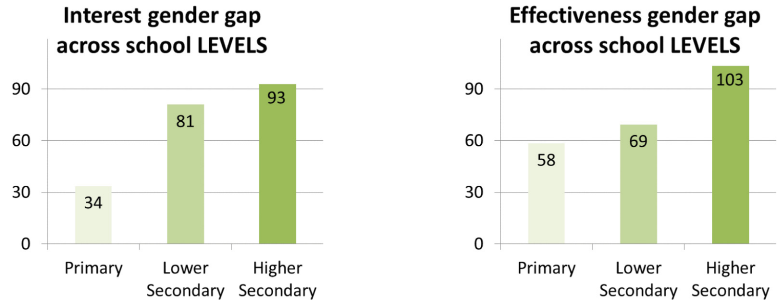

Fig. 3. Gap indicators across school LEVELS (values per thousand teachers)

Table 8. Answers to Q1 (*Interest*) for school years disaggregated by level of school

	2015–16			2016–17			2017–18		
	P	L	H	P	L	H	P	L	H
E	1,821	960	442	2,440	1,080	467	1,345	556	232
F	31	40	27	42	36	35	26	17	17
M	117	149	86	124	136	88	60	53	38

E = equally students of both sexes
F = female students more
M = male students more

Table 9. Answers to Q2 (*Effectiveness*) for school years disaggregated by level of school

	2015–16			2016–17			2017–18		
	P	L	H	P	L	H	P	L	H
E	1,606	865	414	2,214	983	442	1,243	505	228
F	100	90	39	127	96	43	69	46	18
M	263	194	102	265	173	105	119	75	41

On the other side, the larger jump of the effectiveness gender gap happens from Lower Secondary to Higher Secondary, which is consistent with the fact that the interest gap indicator tells girls have lost their interest in Lower Secondary.

An additional element contributing to the importance of the observed phenomenon (beyond the fact that teachers answered anonymously) is that the CS activities done in PiF were not elective for students but all students were exposed to them.

4.2 Disaggregated Data

We analyzed data disaggregated by level of school and by year of school to investigate the robustness of our results also within each school year and each school level (teachers provide their school level answering to the yearly questionnaires). Table 8 (for Q1) and Table 9 (for Q2) show data for school years from Table 6 disaggregated *by level* of school.

We show in Table 10 (for Q1) and Table 11 (for Q2) data for school levels from Table 7 disaggregated *by year* of school. Note that the sets of data in Tables 8 and 10 (resp. Tables 9 and 11) are the same sets of data, but presented with a different organization, for a better clarity.

Again, to make sense of these disaggregated data we considered the two normalized indicators previously described, but this time we computed them on

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Table 10. Answers to Q1 (*Interest*) for school levels disaggregated by year of school

	Primary			Lower sec.			Higher sec.		
	Y1	Y2	Y3	Y1	Y2	Y3	Y1	Y2	Y3
E	1,821	2,440	1,345	960	1,080	556	442	467	232
F	31	42	26	40	36	17	27	35	17
M	117	124	60	149	136	53	86	88	38

Y1 = 2015–16 **Y2** = 2016–17 **Y3** = 2017–18

Table 11. Answers to Q2 (*Effectiveness*) for school levels disaggregated by year of school

	Primary			Lower sec.			Higher sec.		
	Y1	Y2	Y3	Y1	Y2	Y3	Y1	Y2	Y3
E	1,606	2,214	1,243	865	983	505	414	442	228
F	100	127	69	90	96	46	39	43	18
M	263	265	119	194	173	75	102	105	41

the basis of disaggregated data shown in Tables 8, 9, 10 and 11. We now discuss them separately for the two different presentations. In Subsect. 4.2.1 we discuss indicators for the data disaggregated by year of school reported in Tables 10 and 11, and in Subsect. 4.2.2 indicators for the data disaggregated by level of school reported in Tables 8 and 9.

4.2.1 Indicators Across School Years for Each School Level

In Fig. 4 we show the two indicators ordered by school year and grouped by level of school. You can see that within each level of school both indicators are decreasing as the school years pass, confirming the decrease seen in Fig. 1 for all levels of school together. Therefore, data disaggregated by school year support our interpretation at the aggregated level (Subsects. 4.1.1 and 4.1.2) that the involvement of teachers in project activities has caused this decrease.

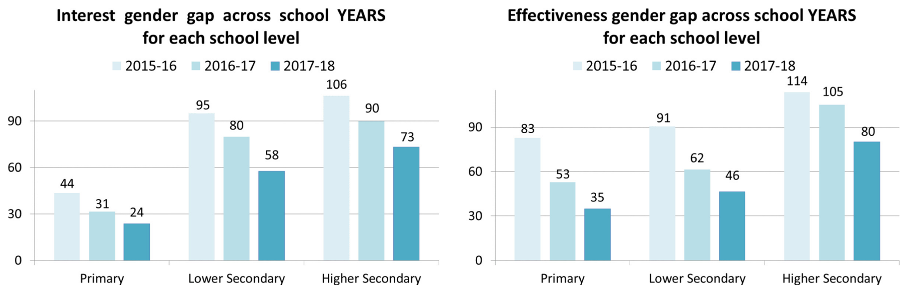

Fig. 4. Gap indicators disaggregated by school YEAR

4.2.2 Indicators Across School Levels for Each School Year

In Fig. 5 we show the two indicators ordered by school level and grouped by year of school. Again, both indicators increase, within each school year, going up with the level of school, confirming the increase shown in Fig. 3 for all years of school together. They also confirm the existence of a larger jump for interest

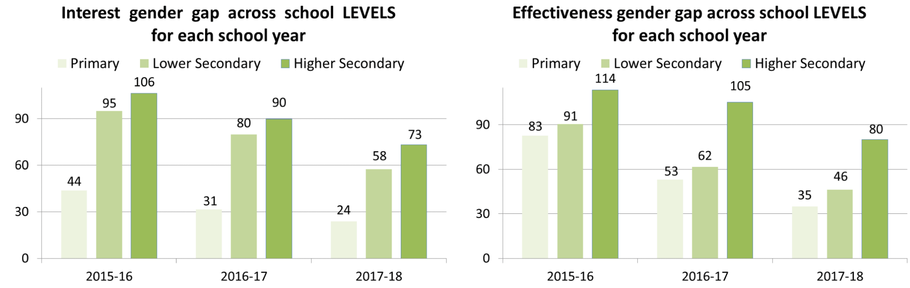

Fig. 5. Gap indicators disaggregated by school LEVEL

in the transition from Primary to Lower Secondary and for effectiveness in the one from Lower Secondary to Upper Secondary.

Therefore, also data disaggregated by school year support our judgment coming from the analysis at aggregate level in Subsect. 4.1.3 that Informatics education needs to be introduced in schools as early as possible in order to improve the attitude of teachers and students towards CS.

5 Conclusions

In this paper we describe the outcomes of a multi-year large-scale study conducted in Italy, where there is no general compulsory Informatics education in schools.

Teachers involved in this study (an average of 3,600 per year, belonging to all levels of school), have voluntarily enrolled in the "Programma il Futuro" project to teach introductory CS courses, grounded on both visual programming computer-based exercises and unplugged content, with dedicated support material.

Over the project years they have periodically filled monitoring questionnaires which examined, among others, whether they considered male students more interested or more effective than female students in carrying out project activities.

We introduced two indicators, called *interest gender gap* and *effectiveness gender gap*, to measure the difference between the number of teachers considering boys more interested (or more effective) than girls and the number of those rating girls more interested (or more effective) than boys.

These indicators therefore gauge what teachers believe about interest and effectiveness of female students relative to their male colleagues. This measure is important, since teachers' beliefs are known to influence students' motivations, hence their future choices. Answers were provided anonymously, a condition that more likely can lead people to honestly provide answers expressing a biased position.

Analysis by school year shows these gender gaps decrease as school years pass, primarily caused - in our opinion - by the nature of project activities and the continuous involvement of teachers. Moreover, analyzing separately in each school year the teachers involved for the first time and those repeating the activities, smaller values of the two indicators are found in the latter groups, reinforcing our interpretation.

When analyzed in the different levels of school (primary, lower secondary, higher secondary) both indicators instead increase in passing from a school level to the next higher up.

The two main outcomes are also supported by disaggregating data by both school level and school year. Within each school level, the behavior of indicators as school years pass confirms the trend measured for the aggregation of school levels. A similar confirmation happens for the analysis across school years.

Our study therefore provides an empirical support to the importance of fighting as early as possible the gender stereotype considering girls performing worse in science than boys. Hence, it also supports the introduction of compulsory CS school education as a way to increase the number of female graduates in computing-related disciplines and ultimately a more diverse IT workforce.

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Rai Cultura, the culture department of Italian national public broadcasting company, is a media partner of the project since February 2017.

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