Science Education in Italy

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SCIENCE EDUCATION IN ITALY

Maria Giulia Ballatore, Anita Tabacco

Abstract: This chapter provides an overview of Science Education in Italy. Firstly, the nation is introduced describing the geographical, political and economic context. Then, the whole education system is presented together with some statistics. These figures support and allow to dipper analyze the current Science Education situation. The study includes students' performance on Science indicators of TIMSS and PISA results as well as general information about the environment and approaches used in Science Education. The figures highlight the importance of science teachers training that supports students' interest in STEMM careers. Further details about future development and the key role of this needed effort are then provided.

Key words: STEMM, Science teacher training, Science career, school system

1. OVERVIEW OF THE COUNTRY

1.1 Geographical location, population and political System

Italy is a South-European country that overlooks the Mediterranean Sea. According to Unesco it holds the largest number of world heritage sites, exactly 55 on a par with China. From a geopolitical point of view, to the north the Alps separate Italy from France, Switzerland, Austria, and Slovenia. Elsewhere, as it is a peninsula, it is surrounded by the sea. The country includes also a variety of islands of different dimensions, of which two major ones. It is divided into 20 regions, 5 of which are autonomous, that is with enhanced powers. Regions can make independent decisions on specific

subjects such as health and local transports. As far as Education is concerned, regions have the power to open and close schools institutions; in principle, Constitution allows extra powers on Education to be assigned to regions by the State following specific legislation, but this has never occurred so far.

Italy is a democratic Republic since 1946 with Rome as a national capital. It is a charter member of NATO and one of the founder states of the European Economic Community and its subsequent successor the European Union (EU). It joined the Economic and Monetary Union in 1999 and it adopted the Euro as a currency from the beginning of its use.

The current population is 60,4 millions based on Eurostat 2019, thus, it counts as 0.78% of the total world population. Looking at the geographical distribution, 69.5 % lives in the urban context and the life expectancy is 84 years with a median age of 47.3 years, among the highest in the world (EUROSTAT, 2020b). The country is recording a population decline and in 2019 it has reached the lower number of births since the 1946.

1.2 Current Situation of economic, technologies and cultural Development

With a Gross Domestic Product (GDP) of 1.789.747 million € (2019), Italy is the third largest economy in the EU and the twelfth largest in the world. Considering the sector of origin, services (tertiary sector) cover 74% of the total GDP, industry (secondary sector) has a share of 24%, and agriculture occupies the remaining 2%(ISTAT, 2020a).

In general, the secondary sector is driven by the manufacture of high-quality consumer goods produced by small and medium-sized enterprises, many of them family-owned. However, this economic development is not equally spread geographically, apart from the tourism sector (tertiary) that involves the entire nation. The majority of the industrial sector, dominated by private companies, is located in the north, while the south lags behind. Indeed, in 2018 GDP per capita in the North-West was equal to 36,200 €, twice as much as in the South (13,700). This has a direct impact on lower employment and higher youth unemployment rates. On average the national unemployment rate in the first fourth months of 2020 is 9.4%, with a 5.7% in the north, 8.3% in the center, and 16.9% in the south (EUROSTAT, 2020c). Considering the age distribution, the 28.1% between 20 and 24 years old are unemployed(ISTAT, 2020c).

On the technological side, Italian Research and development (R&D) intensity (expenditure on R&D as a percentage of GDP), sees a slightly increase in the last years passing from 1.37 in 2017 to 1.43 in 2018. The figure is below the EU average, mainly driven by Germany (3.14), Sweden (3.32), and Denmark (3.13) (OECD, 2019). To foster technological development, the

government has set dedicated investments called “Industry 4.0”. These involve different sectors from Education to Industry. The main goal is to support the new challenge that the factories need to face in term of skills, instruments, technologies and services.

Referring to the last available statistical analysis on cultural behaviors by ISTAT (*Istituto Nazionale di Statistica*), in 2018 cultural participation recorded a slight increase compared to the previous year, going from 64.1% to 64.9%(ISTAT, 2020d; OECD, 2020a).

The observed increase is mainly driven by visitors to monuments and archaeological sites (+2% compared to 2017) and by those who attended concerts of music other than classical (+1.4%).

Considering the geographical distribution, residents in the Center-North are the most active in terms of cultural participation and are distinguished by the lowest overall abstention rates.

State museums institutes registered over 55 million visitors, an increase of about 10% compared to 2017. More than 60% of the visits concerned facilities in the Center of Italy.

The editorial production in 2017 remains concentrated in large publishing houses (80%). In the same year, the publication production amounted to over 70 thousand books, an increase compared to 2016 in the number of titles (+9.3%) and in print run (+14.5%).

The expenditure allocated by Italian families to culture and leisure remains virtually unchanged as a percentage of total consumption expenditure (just under 7%).

2. OVERVIEW OF THE EDUCATION DEVELOPMENT

2.1 Education system and policy

Education is compulsory between 6 (corresponding to the first year of the primary school) and 16 years old (typically, the second year of the upper secondary school). However, young people have the right to receive - and employers have the obligation to provide - formal training until they are 18 years old, when they reach the legal age.

Before compulsory schools, children can attend *asilo nido* (nursery or kindergarden), normally provided by municipalities or private institutions, until they are 3. From 3 to 6 years old they can attend *scuola dell’infanzia* (pre-school). At 6 years pupils start primary school which lasts for 5 years; thence, they join lower secondary school, which lasts for 3 years. Both levels are common to all students and share a nationwide curriculum. At the

beginning of the upper secondary school, students choose between three tracks, all of which last for five years and lead to a final exam: *liceo* (Lycée), more academically oriented; technical school; professional school. Alternatively, some pupils can follow 3 or 4 years of vocational courses delivered by regional authorities. After having completed their final exam, students can join universities that follow the Bologna process structure: the Bachelor degree is obtained after three years, whereas the Master degree after further two. Some courses, like Law or Medicine, have a full track of five or six years.

It should be noted that 86% of students complete the full track of secondary school (in most cases up to 19 years of age) (EUROSTAT, 2020a; MIUR, 2020a). Little above 50% of each cohort attend tertiary (university) education and just 34% reach a degree (ALMALAUREA, 2020).

Preliminary figures for 2020-21 suggest that in the new school year – which follows a lockdown of 18 weeks due to Covid-19 – 8.3 million students from 3 to 19 years will attend classes: 7,507,484 in state schools and 860,000 in private ones (MIUR, 2020c). Official university enrollments are not yet known, as they can take place later in the year. However, preliminary information from university suggest that the number of overall students should be close to that of last year (1,750,000 total enrolled and 300,000 new entrants) despite the impact of the Covid-19.

Government policies in the recent years have focused on:

- expanding childcare opportunities between 0-2, from the current 24.7% of the relevant population to the European target of 33% (ISTAT, 2020b);
- fighting against school dropout, which amount to 13.7% of the young population, with spikes above 20% in Southern regions (EUROSTAT, 2020a);
- raising the percentage of young people who obtain a university degree, currently at 27% (OECD, 2020b).

Other areas of concern are post-secondary vocational education and training, which is largely absent in Italy, and the low average level of learning outcomes vis-à-vis other advanced countries.

2.2 Statistics on the national education

In Table 1, we recap the whole gamut of school and university levels, the corresponding ISCED level and the number of attending students in the 2017-18 school year, the most recent to include both public and private pupils (MIUR, 2020a).

Table 1 Students and teachers distribution referring to 2017-2018 school year(OECD, 2020a)

Age	Level	Isced 2011	#students	#teachers
0-2	Kindergarten	0	354,641	
3-5	Pre-school	0	1,491,000	101,136
6-10	Primary	1	2,754,000	278,640
11-13	Lower secondary	2	1,731,000	196,770
14-18	Upper secondary*	3	2,688,000	295,722
19-21	Bachelor	6	1,045,893	
22-23	Master	7	644,941	

*This figure does not include students in vocational education and training who attend courses provided by regional agencies up to 16 and 17 years old.

Schools were 8,636 in 2019 over the entire country: most include more than one building and encompass from pre-school to lower secondary. Overall, there are 40,000 buildings, most of which built from the Sixties to the Eighties.

School teachers in 2018 were 872,268, of which 135,025 on a temporary basis. The latter figure is likely to overcome 200,000 in the current year. The ratio students/teachers is around 10, one of the lowest among OECD countries. About 150,000 teachers are fully allocated to support 270,000 special needs students. Teaching or researching university personnel includes: 33,969 full or associate professors who are obliged to teach; 27,759 adjoint professors; 12,601 full time researchers; 6,216 researchers on a temporary basis (MIUR, 2020b). The number of students per university lecturer is around 30, one of the highest among advanced countries (ANVUR, 2018).

2.3 Educational research and international collaboration

The Italian university field relating to the education and training of teachers is located mainly in the Departments of Education. Each department has 5-year courses for pre-school and primary school teachers as well as educational science research centers for school and extracurricular issues (including theory and history of educational and training processes, teacher training, interculturality, interventions on diversity, education and socialization processes, multimedia learning, adult education) and specifically methodological, didactic and experimental research. At the same time, in all the other departments related to secondary education (i.e., Mathematics,

Literature, Physics, Biology, etc.) can exist some thematic research areas inherent teaching.

The Italian National Research Council has one dedicated institute, the *Istituto per le Tecnologie Didattiche*, devoted to the study of educational innovation achieved through the use of Information and Communication Technologies. Moreover, at the national level, there exist various private foundations that have as main objective educational research.

All these research centers can receive competitive national or European funding related to the innovative and challenging projects (i.e., PRIN, SIR, H2020, Erasmus+, etc). Moreover, they can count on strong networks either national (i.e., *Avanguardie Educative*) or international (i.e., E-Twinning). These relations focus both on the training of teachers and research for implementation and teaching improvements as well as for sharing good practices.

3. CURRENT SITUATION OF SCIENCE EDUCATION

3.1 Policies and standards

Currently, there are not professional standards for science educators and teachers in general. Pre-school and primary teachers are enabled to teach with the degree. Secondary teachers, instead, are divided into *Classi di Concorso* (CdC) based on subject taught. To have the right to teach, they need to pass a national exam for each CdC.

In the recent past the Ministry of Education, in collaboration with the Conference of Deans of Science and Technology and Confindustria established a policy in favour of science education call *Piano Lauree Scientifiche,* Plan for Science Degrees (MIUR, 2004).

This plan aimed at:

- promote enrollment in scientific degree courses, also aiming at promoting a gender balance, by strengthening the offer of guidance;
- reduce university dropouts and improve students' careers through the introduction of innovative teaching tools and methodologies;
- implement training, support and monitoring of the activities of the first years of university;
- carry out self-assessment activities for students of upper secondary schools to verify the preparation for entry into universities concerning the required requirements and increasing the awareness of their knowledge to choose the training path;

- provide science teachers opportunities for professional growth through active participation in the planning of activities carried out jointly with the University.

3.2 Curricula, digital resources and teacher training

At primary and lower secondary level the curriculum is defined by the National Guidelines (MIUR, 2018a), which provide for Science and any other subject goals for the development of skills, that should be reached by the end of the grade 3 (corresponding to the third year of primary school), by the end of the grade 5 (end of primary school) and by the end of grade 8 (end of lower secondary). Learning objectives cover the following content areas:

Primary level:

- Exploring and Describing Objects, Materials and Transformations
- Observing and Experimenting in the Field
- Man, Living Things, and the Environment

Lower secondary level:

- Physics and Chemistry
- Astronomy and Earth Science
- Biology

At upper secondary level curricula are defined by National Guidelines for Lycée, technical, professional and vocational tracks (MIUR, 2018b).

In order to become a teacher at primary school, candidates are required to obtain a degree in Primary School Education. The academic component of the degree is the same for all graduates, usually with some exams that cover element of physics, chemistry and biology; only after graduation teachers specialize in a particular disciplinary field during their school internship.

From lower secondary education, teachers are subject specialist and are required to get a degree related to the subject taught. For example, to teach mathematics and science, teachers must hold a mathematics, physics, biology, life sciences or geology degree.

3.3 Student assessment and achievement

Italian student achievement in science are measured by TIMSS (TIMSS & PIRLS International Study Center, 2015) and PISA (OECD, 2018b), two international surveys that base their assessment respectively on “what students know” and “what students are able to do with their knowledge”.

Latest and available results come from 2015 round of TIMSS and 2018 round of PISA, the former on grade 4 and 8 performances and the latter on 15 years students, thus “covering” primary, lower and upper secondary school.

In TIMSS, at grade 4 the Italian average score is 516 points (overall average score is 500, with standard deviation of 100), in line with other European countries like Serbia, Netherlands, and Spain but significantly lower than worldwide top performers like Singapore (590 points), South Korea (589), Japan (569) and European ones like Finland (554 points) and Poland (547).

At grade 8 the Italian average score is 499 points, behind all European countries with the exception of Malta and far away from Slovenia (551), England (537) or Sweden (522).

From a time perspective the trend of grade 4 achievements is negative, with average score steadily decreasing from the 537 points in 2007 and the 524 in 2011 round, while it remains quite stable for grade 8, 495 in 2007 and 501 points in 2011 round.

TIMSS also provides results according to content domains. Thus, while grade 4 students perform better in Life Science (519 points) with respect to Physics (513 points) and Earth Science (510 points), grade 8 students suffer the most in Chemistry (487 points), the less in Earth Science (514 points) and are in line with overall results in Biology (496 points) and Physics (496 points).

Grade 4 achievements are characterized by a relevant gender gap: the 9 points difference in favor of boys (521) with respect to girls (512) places Italy at the top of an undesirable ranking, only exceeded by the 10 and 11 points difference observed in Hong Kong and Korea. Grade 8 results confirm a gender gap issue in lower secondary school, with a similar magnitude of 10 points difference between boys (504) and girls (494) achievement levels.

In PISA, the Italian students' score in science assessment is 468, lower than the average OECD one (489) and lower than those of vast majority of participating European countries. Further national comparisons are shown in Fig. 1(OECD, 2018a).

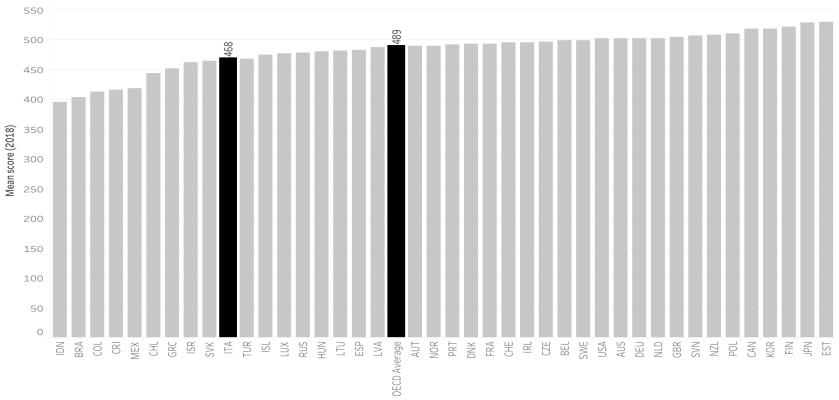

Figure 1 Average PISA science score by nations

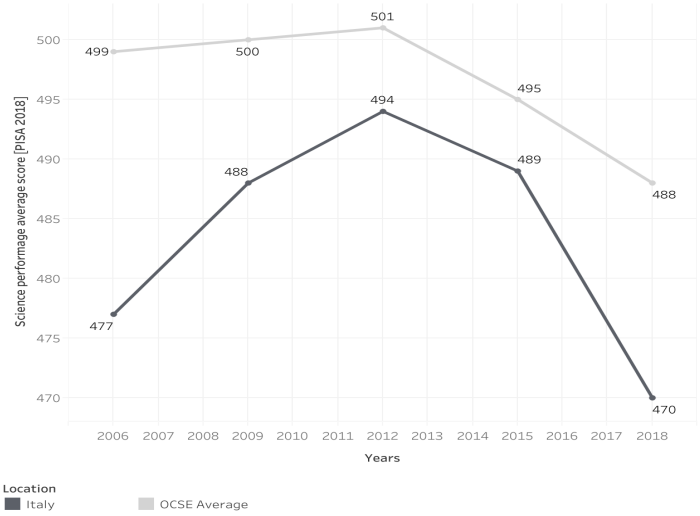

Figure 2 Italian science performance score on PISA compared to the OCSE average

Moreover, 2018 round confirms and exacerbates a path of decline observed between 2012 (494) and 2015 (481), thus offsetting the positive trend started in 2009 (489) (see Fig. 2).

Fig. 3 shows the negative gradient in science achievements once we move from northern to southern regions of Italy.

Fig. 4 describes the differences among tracks: while academically oriented track performs better than OECD average score, technical, vocational and professional tracks lags behind.

In Italy there are no differences in science achievement between boys and girls, a result in line with overall picture, where girls outperform boys by a negligible amount, 2 points.

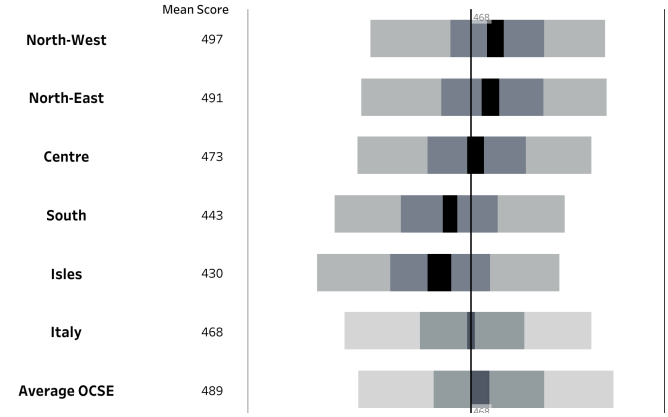

Figure 3 Science score distribution among Italian geographic areas compared to the national and the OCSE values

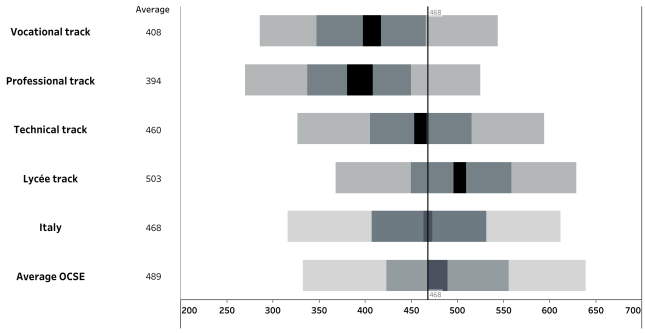

Figure 4 Science score distribution among upper secondary schools' tracks compared to the national and the OCSE values

3.4 Science and technology venues and centers

According to the 2019 survey carried by the ISTAT(ISTAT, 2018), in Italy there exist about 450 science museums and centers, two out of three devoted to Natural Science and the rest to Science and Technology. They are no homogeneously widespread over the country, with regions like Emilia Romagna, Lombardia and Trentino-Alto Adige that stand out for their museum and exhibition centers.

Unfortunately, ISTAT does not provide any aggregate number on annual visitors; in spite of this lack of information, for some of the most important science museum in Italy data are available and collected in Fig. 5.

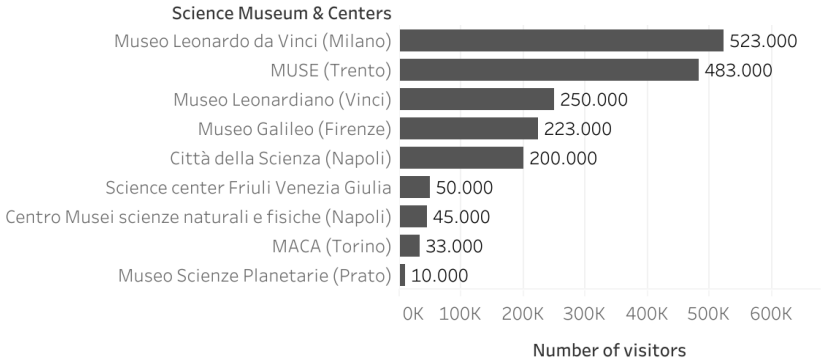

Figure 5 Number of annual visitors in science museum (2018)

3.5 Utilizing emerging technologies

In general, Education recently has seen a variety of incentives (i.e., *Piano per la Scuola Digitale, Industria 4.0, Programma Operativo Nazionale, etc.*) to foster technological development. This mainly involved structural

equipment and infrastructure, regardless of teaching methodologies. Science Education does not benefit from any systematic strategy to introduce technologies like augmented reality, virtual reality or artificial intelligence.

Nevertheless, in recent years many schools have undertaken an increasing number of projects related to coding and robotics, in particular at the primary school level where coding is introduced in a funny way to youngest students.

During Covid-19 lockdown, schools moved to the distance learning environment. This has caused a rapid spread of a digital learning environment.

4. REQUIREMENTS FOR FUTURE DEVELOPMENT OF SCIENCE EDUCATION

Science Education is becoming a key element for the reduction of skills mismatch, given the increasing demand for scientific and technological occupations. Only with a strong and robust science education, students are free to choose scientific careers to fill the labor market's needs.

For this reason, special attention should be driven to early education (pre-school and primary education) especially when referring to the gender gap. This will require a qualitative and quantitative improvement in the teachers training. In particular, regarding the pre-school and primary school teachers, their university degree should include the specialization either in Science or Literature. This will allow them to preferably teach Mathematics and Science only with strong educational basis.

Equally, special training about Science Education and their teaching technique should be reinforced for upper secondary teachers during their university study. Currently, new teachers have to follow some mandatory courses about pedagogy, psychology, anthropology and teaching technique. These are general courses and do not refer specifically to Science Education.

Teaching methodologies in Italy are generally quite old and grounded on one-way transmission from teacher to students, as documented by OECD-Talis (OECD, 2020a). This is true also of Science Education, where teachers rely typically on front explanations and home assignment rather than on understanding of physical phenomena through direct experimentation at school. A few attempts are being made to try to redefine the teaching standards in Science: an example is the project on Physics by CERN and Fondazione Agnelli aimed at lower secondary schools. The project is aiming at fostering scientific culture and transmit science and technology concepts in an engaging way, exploiting and promoting Inquiry Based Learning as a possible different approach to study science with respect to traditional frontal teaching.

Demographic trends suggest that the overall number of students will fall by 1 million (about an eighth) by 2030, starting from early grades: this implies

a reduction of 65,000 jobs among teachers. Hence, in the next decade new entrants in schools will be limited to a partial replacement of retiring teachers. This implies the strong need to update and retrain existing Science teachers, especially as far as their teaching methodologies are concerned, in order to improve students' achievements.

5. DISCUSSION AND CONCLUSION

In order to enhance the level of knowledge and competencies in Sciences by Italian students, the starting point has to be the improvement in the quality of Science educators. Currently, as we saw, Science teachers are aged and, generally speaking, do not possess all the teaching skills necessary to engage and motivate students in the field at different grades. Policies to upgrade Science teachers' skills should include at least three aspects.

First, as far as existing teachers are concerned, they need a massive and compulsory training campaign to enlarge the set of teaching tools at their disposal to teach Sciences, especially focused on designing and running practical experiments. This implies a huge investment from the Government to finance such training, possibly thanks to Next Generation EU. Secondly, science teacher skills improvement has to be assessed before returning them to the classroom: in case they fail to achieve an adequate level, they will not be allowed to resume teaching and will have to undertake further training until they reach a satisfactory standard. The assessment outcome should also be a component of teachers' advancement along a career ladder, which does not yet exist in Italy but is currently under discussion. Thirdly, teachers' wages should be redefined in order to recognize effort and competencies on the part of teachers. Currently the only criterion for teachers' wage increase is seniority: as said, a career mechanism is under discussion. A greater progression in wages could help to motivate teachers who invest more heavily in their training and foster the importance and the key role of science educators.

As far as new teachers are concerned, an important implication is that, considering the high demand for science and technical figures in the private sector, not enough young graduates are motivated to go into teaching. As clearly shown in fig. 5.3 of "Gli insegnanti nella scuola italiana"(Argentin, 2018), the probability to become a teacher is strongly negatively related to the final graduation mark, used as proxy of their competencies: hence, best graduates shy away from the teaching profession. This is especially true for Science teachers. Incentives, such as wage premia, should be considered in order to attract the best graduates into the profession.

All in all, planning for the long-term professional enhancement of Science Educators should become a key priority to support the future development of the country.

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