Student enrolment in geology from a systemic earth science education perspective: an Italian case study

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The knowledge of our planet should represent a common background for active and responsible citizenship and should be provided by the school. Although earth science is present in all Italian school curricula, most teachers do not have a strong geological background and that affects earth science education. On the other hand, the number of students that enrol in geology as an academic major has significantly decreased in the last 20 years. In this paper we suggest that the teaching should be suggested to geology students as a career possibility, so to improve the quality of the geological education in school and also on the enrolment in geology courses.

La connaissance de notre planète doit représenter un fond commun pour une citoyenneté active et responsable et doit être apportée par l'école. Bien que les sciences de la terre soient présentes dans tous les programmes scolaires italiens, la plupart des enseignants n'ont pas une solide formation géologique et cela affecte l'enseignement des sciences de la terre. D'autre part, le nombre d'étudiants qui s'inscrivent en géologie en tant que discipline académique a considérablement diminué au cours des 20 dernières années. Dans cet article, nous suggérons que l'enseignement soit proposé aux étudiants en géologie comme une possibilité de carrière, afin d'augmenter la qualité de l'enseignement géologique à l'école ainsi que l'inscription aux cours de géologie.

El conocimiento de nuestro planeta debe representar una base común para una ciudadanía activa y responsable el cual debe ser proporcionado por las escuelas. Aunque las ciencias de la tierra están presentes en todos los planes de estudios de las escuelas italianas, la mayoría de los profesores no tienen una sólida formación geológica y eso afecta la educación en ciencias de la tierra. En otro orden de ideas, el número de estudiantes matriculados en cursos de geología como especialidad académica ha disminuido significativamente en los últimos 20 años. En este artículo recomendamos que se sugiera la docencia a los estudiantes de geología como una alternativa de carrera, para mejorar la calidad de la educación geológica en la escuela y también en la matrícula en los cursos de geología.

Introduction

At the end of high school few students decide to pursue a career in geoscience, and sometimes the low enrolment puts the existence of geology courses at risk. This is the situation in Italy and it is not a unique situation. And this is just the tip of the iceberg of a struggling structural situation related to earth science education system. Here we define the earth science education system as the ensemble of actors (schools and university students and professors), the teaching-learning process, and school and university curricula, as well as the interactions among them.

In the last decades many authors have emphasised the importance of earth science literacy for society. Mayer (1995) indicated the need to integrate the science curricula within the frame of the earth system, rather than following a strictly disciplinary approach, and concluded that earth science teachers should be leaders of this paradigmatic change. The philosopher Morin (1999) stresses the importance of earth science for the education of future citizens. Despite the recognised significance of that area of knowledge, the status and relevance of earth science are quite low, as proved by several international surveys (King, 2013; Greco & Almberg, 2016; Gorfinkiel & Frick, 2019). Orion (2017) defines this situation as a disturbing gap.

In this article, using secondary data that are publicly available on governmental websites, we analyse the Italian earth science education system with the aim to put forward some suggestions for the improvement of the actual situation. Italy is a country largely exposed to seismic, volcanic, and hydrogeological hazards; moreover, geoscience are represented, even if for a few dozen hours a year of teaching time, in all the national curricula of natural sciences. Both these features could be strengths in order to improve earth science literacy. In this context, the agreement between the National Association of Natural Sciences Teachers (ANISN) and the Italian Geological Society (SGI), to improve earth science teaching is welcomed.

After a short description of the earth science curricula in Italian primary and secondary school, we focus on geology higher education, as we identify it as the core where it is possible to make changes that could generate positive feedback on the whole earth science education system.

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Earth science in school

The Italian school system is organised into 5 years of primary school (usually children start school at 6 years old), followed by 3 years of middle school and 5 years of high school.

Natural sciences – and earth science within them – are taught in all levels of Italian school, from the primary to high school. According to the most recent

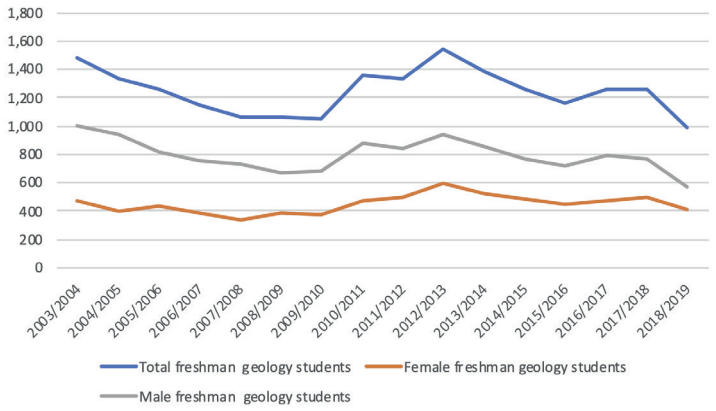

Figure 1: Total number of geologist freshmen, female and male geologist freshmen between 2003 and 2018.

National Indications of the Italian Ministry of Education (*Ministero dell'Istruzione, Università e Ricerca*, hereafter MIUR), in the first years of primary school the children are expected to observe the characteristics of soil and water and to interpret the natural transformations of the environment, including the cyclic changes due to astronomic movements (MIUR, 2012). Usually primary teachers are graduates of a 5-year pedagogical studies programme in higher education, with a deep background in pedagogy and general knowledge in all the disciplines, as a single teacher takes care of the whole spectrum of contents.

At the end of middle school, students should be able to explain astronomical mechanisms such as eclipses, the alternation of day and night and the sequence of seasons, to recognize the main rock types, to describe the internal structure of Earth and its movements – plate tectonics – and to identify volcanic, seismic and hydrogeological risks of the area they live in. In middle school, teachers are specialised in different subjects and one teacher takes care of math and science; math and science teachers may have very different academic science backgrounds, such as mathematics, physics, chemistry, agriculture, biology (in most cases), natural sciences and even geology.

Primary and middle school follow the same curriculum for all pupils, whereas at the end of middle school the students have to choose the kind of high school: lyceum (which prepares specifically for university), technical institutes (which prepare technicians for industry, commerce, tourism) and vocational institutes (which prepare skilled workers in specialised fields). Just to give an idea of the students' choices, in the 2019/2020 school year, around 55.4% of students enrolled in lyceum (among them 15.6% in sciences lyceum and 8.4% in applied sciences lyceum), 31% in technical schools and 13.6% in vocational schools (MIUR, 2019a). As a whole, in the 2019/2020 school year the total of 2,626,226 high school students was distributed as follows: 49.8% in lyceum (sciences 366,280, applied sciences 188,467), 31.5% in technical schools, and 18.7% in vocational schools. The comparison between the two distributions shows that the number of enrolled students in lyceum is significantly growing (MIUR, 2019b).

In high school, earth science topics are taught together with biology and, in lyceum, also with chemistry, within the Natural Sciences subject. All of the high school curricula include at least two hours per week of natural sciences in the first two years. The science-oriented high school (sciences and applied sciences lyceum) includes even more earth science contents. At the end of high school, students should have encountered the earth science topics which are shown in ***Table 1*** for the different high schools and the students' age, according to the 'Guidelines' (MIUR, 2010a, 2010b).

A study carried out by Realdon *et al.* (2016) shows that the time that teachers devote to earth science teaching gradually decreases over the five years of the upper secondary schools, to leave more space for chemistry and biology. For example, teachers often choose to anticipate the earth science topics of the 5th year (***Table 1***) in the 3rd year, to leave just biology and biochemistry in the last school year, which ends with the national final examination. This is probably due to the fact that the vast majority of natural science teachers are biologists, followed by natural scientists, and then other fields of science, including geologists in a few cases. This situation undermines the relevance of earth science in school and the teaching-learning processes, especially in the use of practical and field-based educational activities, which are one of the pillars of earth science education.

Earth science in higher education

Following the Bologna Process, higher education was reorganised into two cycles: the Bachelor Degree (1st cycle of three years) and the Master's Degree (2nd cycle, two years). In a few cases (e.g. for the degree courses in medicine) single-cycle master's degrees exist, lasting 5 or 6 years. Access to university requires a high school diploma for both 1st-cycle and single-cycle master's degrees, and the bachelor's degree for the 2nd cycle master's degree.

In the first cycle students will gain an adequate mastery of general scientific methods and topics and the acquisition of specific professional knowledge. In the second cycle, advanced level training is offered in

Table 1: Earth science topics in the science courses for the different Italian high schools and years, as suggested by the Italian Ministry 'Guidelines' (MIUR 2010a, 2010b).

High School	Lyceum	Technical Institute	Vocational Institute
First two years (age 14 and 15)	- astronomical geography - geomorphology - hydrosphere - atmosphere	- astronomical geography - hydrosphere - atmosphere - rocks and minerals - volcanoes - earthquakes	- astronomical geography - hydrosphere - atmosphere - rocks and minerals - volcanoes - earthquakes
Third year (age 16)	- minerals and rocks - volcanoes - earthquakes - orogenetic processes		
Fourth year (age 17)	- No earth science contents		
Fifth year (age 18)	- meteorological phenomena - plate tectonics - relationships among hydrosphere, geosphere and atmosphere - biogeochemical cycles		

order to perform highly qualified activities in specific areas.

In the following, we focus on the three-year course "Geological Science" (previously also called "Earth Science") because here we have the interface between high school and higher education. In Italy there are 28 universities that offer a first-cycle course in geological science[1]. The data provided hereafter refer to these universities, are freely available on the MIUR website[2] and cover the period 2003-2019.

Between 2003 and 2019 the number of students enrolled in the first year of the geology courses ranges from a minimum of 986 students in the academic year 2018/2019 to a maximum of 1,541 in 2012/2013 (in ***Figure 1*** the data are reported separately for the total freshmen geology students, female and male freshmen geology students). The peak of geology freshmen in 2012/2013 is evident not only in absolute terms, but also in percentage, taking into account that it corresponds to a period when overall enrolment in higher education was relatively low (***Figures 2 and 3***).

On a qualitative basis, it is noteworthy that the peak of enrolment in geology courses corresponds both to relevant seismic activity in Italy (earthquakes of Aquila, 2009, and Emilia, 2012) and to intense outreach activities on earth science linked to the International Year of Planet Earth (2008) and to the selection of students for the International Earth Science Olympiad (IESO) through the national Olympiad. In fact, the national selections for IESO give the opportunity to school students to become deeply engaged in earth science learning and to discover their interest in subjects that could be addressed in a geology course. Italy hosted the IESO in 2011. In the same period sessions on earth science education research became an established presence in geology scientific conferences.

Among students enrolled in the first year of the geology course there is a percentage of students that move from other courses; this percentage seems to have decreased in the considered period to reach the present value of 18%, which is lower than the mean of 23% of the overall three-year courses.

The gender ratio between females and males is quite imbalanced (nearly 1:3; ***Figure 4***), with the percentage of female students enrolled in geology courses having increased from a low of 30% in 2004/2005 to 42% in 2018/2019, mainly due to the decrease in enrolled male students. The percentage of female students varies quite a lot across the country, with the highest proportions of female students being in the islands (47%) and southern region (46%), whereas in the northern and central regions the percentage is 42% and 35%, respectively.

When we look at the type of school where geology freshmen come from, we discover that in the academic year 2018/2019 almost two thirds came from lyceum schools (61%), one third from technical schools (30%), few of them from vocational school (7%) and pedagogic school (2%). These percentages remain almost constant in the whole considered interval, with a slight positive trend for lyceum compared to technical schools. The number of students that choose geology coming from lyceum is below the corresponding value in other science courses (80% in biology, 83% in physics, 72% in chemistry, 78% in math).

At the end of high school, all Italian students are assessed in a national exam. If we look at the evaluation that the geology students gain in that examination, and we separate data for males from females, an interesting pattern appears (***Figure 5***). There is a significant difference in the percentage of females and males in each class of assessment, and females are predominant in the class of high assessment. As a whole, the majority of students have a low class assessment (***Figure 6***) and just 11% are in the top two class scores. Civil and environmental engineering, biology, and physics courses look much more effective in attracting high school students with the best assessments (***Figure 7***).

1 ***https://www.universitaly.it/index.php/cercacorsi/universita***. The Geological Science course is identified by the code L-34, the Earth Science Course with the code 16.
2 ***https://anagrafe.miur.it/index.php***, data dowloaded on September 2020.

Figure 2: Total number of freshmen by academic year.

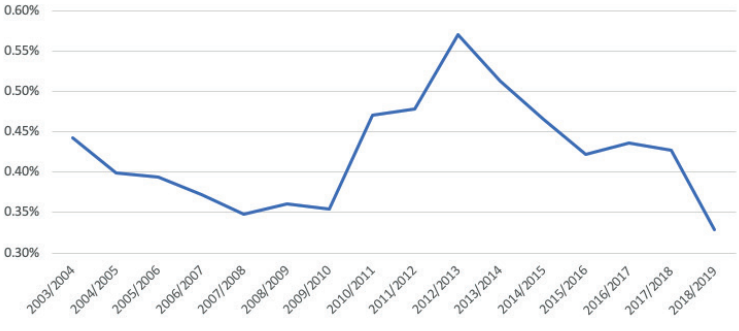

Figure 3: Percentage of geologist freshmen of the total freshmen in Italy.

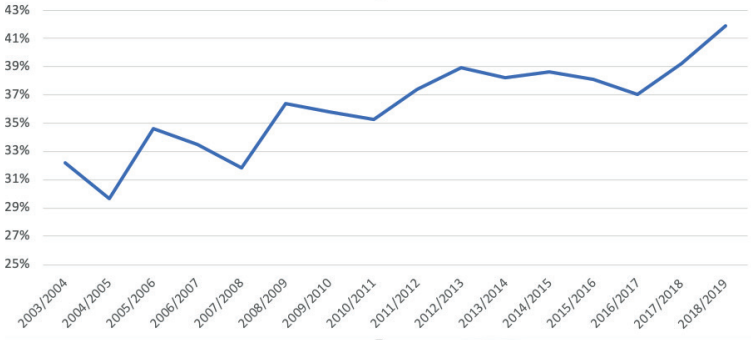

Figure 4: Changes in the percentage of female freshmen in the considered period for geology courses in Italy.

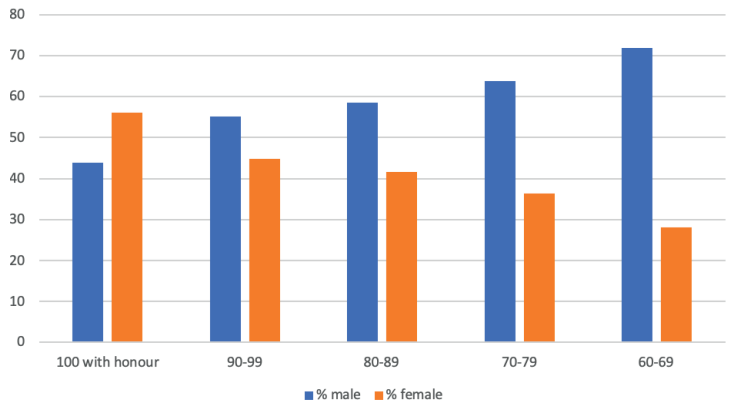

Figure 5: Distribution of male and female geology students by classes of assessment in the academic year 2018/2019.

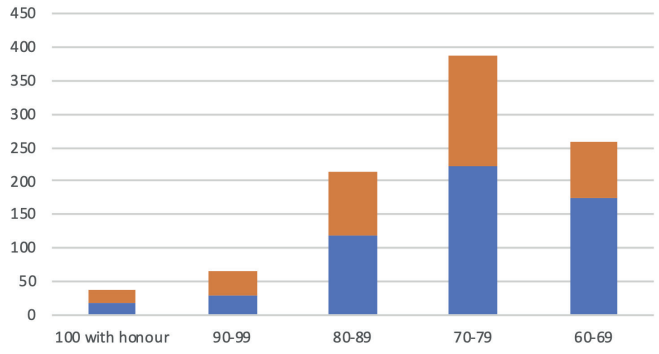

Figure 6: Distribution of geology freshmen by classes of assessment in the academic year 2018/2019.

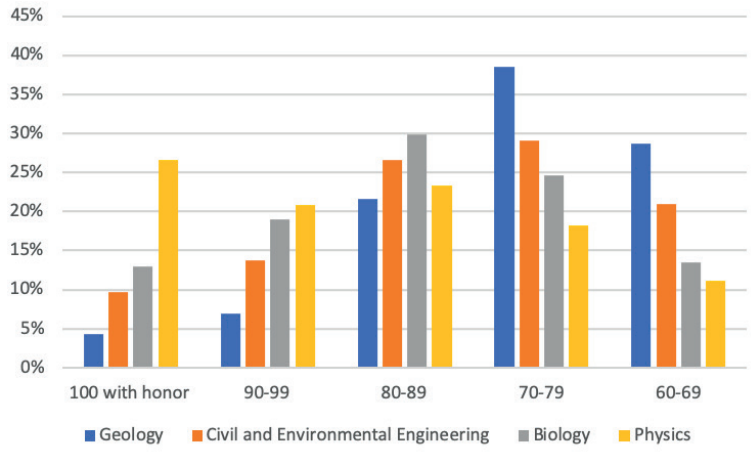

Figure 7: Entry grade distribution comparison among some scientific degree courses in the academic year 2018/2019.

Post-university formation

After a three-year degree, students can continue their studies with an additional two-year master's course such as geophysics (national academic course code: LM-85) or geological science (national academic course code: LM-86).

In the Italian academic system it is possible to integrate the master's programmes to take classes that will allow students to qualify for teaching at school. However, this is not a common choice of geology students.

It is well-documented that – in Italy as well as in all of southern Europe – geoscience is generally taught by teachers without a strong geological background. In contrast, in northern Europe earth science contents, if any, are taught in a geography discipline by geographers (Greco & Almberg, 2016; King, 2013; Realdon *et al.*, 2016). In fact, the majority of the academic degrees leading to teaching earth science in middle and high schools do not involve a specific academic background in earth science. In particular, the majority of natural sciences teachers are biologists, a quite predictable output considering that the number of students enrolled in biology is almost nine times higher than the students enrolled in geology. This represents positive feedback that amplifies the gap.

Only in recent years have aspiring teachers been required to complement their training in areas of knowledge not covered in their academic career. This means, for example, that an aspiring teacher with a chemistry major will have to acquire credits in biology and earth science to be eligible for selection.

The importance of science teachers in determining the career choices of their students emerged in a survey that involved more than 700 geology students (Greco & Gualtieri, 2010). Among the motivations to choose the geology course, the degree of their teachers in geology or natural sciences represents an important factor. It is also important to note that in the same survey many geology students reported that they choose geology but they were also tempted by biology or natural sciences. From this data it seems that having more geologists as science teachers in high school could make a difference in motivating students' choice.

Conclusions

The Italian earth science education system presents several critical issues that affect the possibility of gaining significant literacy in earth science to the advantage of the whole society:

- there is a need to improve the high school curricula with better integration and organisation of earth science content;
- there are few school teachers with an earth science background;
- there are few school students who choose geology as a career;
- there are few geology students who invest the time and resources to get the education credits needed to become teachers.

We would like to focus on the last aspect because it is the one where the geological community, including geoscientists and professional geologists, could have more direct influence:

1. Including teaching as a possible career for a geologist is basically a cultural choice. Humans are social beings and geology students do not escape the influence of the community where they grow up. The way

the established geoscientists and professional geologists comment on teaching as a profession affects the perspectives and decisions of geology students.

2. Encouraging the geology students to obtain the academic credits that will allow them to teach at school will increase the spectrum of their job opportunities. In order to work as professionals, a geologist must be registered in the *Consiglio Nazionale dei Geologi* (CNG), which represents the category of their expertise, guarantees the quality of the service provided and offers continuous training. As of 11 September 2020 almost twelve thousand (11,835) geologists were included in the CNG. Of those, 1,751 are public employers, including all of the geologists that are working as school teachers (data from the secretary of the CNG). As a matter of fact, teaching is already one of the possible professional activities for a geologist.
3. Last but not least, education credits deal with communication and reasoning skills, which could benefit any professional geologist/geoscientist.

Of course, besides this challenging effort, the whole geoscience community should collaborate with school teachers to improve the quality of earth science teaching and learning. Different experiences, both at national and international level, highlight how the sharing of good practices or tools, possibly at low cost or for common use, can be the first step in the promotion of the more exciting, more engaging and therefore more effective teaching of earth science.

The new magazine of the SGI, 'GeologicaMente' (which can be translated as 'Geologically' or, with a play on words, 'Geological Mind'), dedicates a large space to the teaching of earth science. We hope that descriptions of laboratory, practical and field activities will be soon included, with strong cooperation among science teachers, geoscientists and professional geologists.

Our aim should be the sharing of good practices, but also increasing knowledge and training in this important scientific field, which also includes, unavoidably, attention to the environment, sensitivity to natural hazards and a culture that looks to the objectives of Agenda 2030 for sustainable development.

References

Greco, R. Gualtieri, A. F. 2010. Studio Geologia perché... Risultati preliminari dell'indagine quali-quantitativa relativa alla scelta del corso di laurea in Scienze Geologiche (I'm studying geology because ... preliminary results of a quali-quantitative survey on geologist students about their motivation for studying geology). *Geoitalia*, v. 33, p. 38-41.

Greco, R. and Almberg, L. (eds.) (2016). *Earth Science Education: Global Perspectives*. Pouso Alegre: IFSULDEMINAS.

Gorfinkiel D., Frick, M. (Eds.), (2019). *Geoscience in Primary and Secondary Education*. UNESCO/IGEO.

King, C. (2013). Geoscience education across the globe – results of the IUGS-COGE/IGEO survey. *Episodes*, 31, 19-30. https://doi.org/10.18814/epiiugs/2013/v36i1/004

Mayer, V.J. (1995). Using the earth system for integrating the science curriculum. *Science Education*, 79, 375–391.

Morin, E. (1999). La Tête bien faite. Repenser la réforme, réformer la pensée (A well-made head: Rethinking reform, reforming thought). Paris, Seuil.

MIUR (2010a). Indicazioni nazionali degli obiettivi specifici di apprendimento per i licei. [National indications of the specific learning targets or lyceum high school]. *Gazzetta Ufficiale, Serie Generale n. 291 del 14-12-2010 - Suppl. Ordinario n. 275.*

MIUR (2010b). Linee guida per il passaggio al nuovo ordinamento degli istituti tecnici e professionali. (Guidelines for the transition to the new technical and vocational institutes]. *Gazzetta Ufficiale, Serie Generale n.222 del 22-09-2010 - Suppl. Ordinario n. 222.*

MIUR (2012). Indicazioni nazionali per il curricolo della scuola dell'infanzia del primo ciclo di istruzione. (National indications for the curriculum of the nursery school and the first cycle of education]. Ministero dell'Istruzione, dell'Università e della Ricerca. *Annali Pubblica Istruzione*, Special Volume 2012, 3-88.

MIUR (2019a). Comunicato 31/01/2019, Iscrizioni on line, ecco i primi dati: il 55,4% degli studenti sceglie i Licei, il 31% i Tecnici, il 13,6% i Professionali. Ministero dell'Istruzione, dell'Università e della Ricerca. ***https://www.miur.gov.it/web/guest/-/iscrizioni-on-line-ecco-i-primi-dati-il-55-4-degli-studenti-sceglie-i-licei-il-31-i-tecnici-il-13-6-i-professionali.***

MIUR (2019b). Focus "Principali dati della scuola – Avvio Anno Scolastico 2019/2020". Ministero dell'Istruzione, dell'Università e della Ricerca. ***https://www.miur.gov.it/-/focus-principali-dati-della-scuola-avvio-anno-scolastico-2019-2020-***

Orion, N. (2017). The relevance of earth science for informed citizenship: Its potential and fulfillment. In Leite, L.; Dourado, L.; Afonso, A. S.; Morgado, S. (eds.), Contextualizing Teaching to Improve Learning: The Case of Science and Geography. *Nova Science Publishers*, 41-56.

Realdon, G., Paris E., & Invernizzi, M.C. (2016). Teaching Earth Sciences in Italian *liceo* high schools following the 2010 reform: a survey. *Rendiconti Online Società Geologica Italiana*, 40, 71–79.