Geografia Fisica e Dinamica Quaternaria
GFDQ 46 (2023), 257-274

DOI 10.4454/98fghr54

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Teachers' perceptions of the effectiveness of teaching Geosciences in Italian upper secondary school

Abstract: Barone A., Rotigliano E., Madonia G., *Teachers' perceptions of the effectiveness of teaching Geosciences in Italian upper secondary school.* (IT ISSN 0391-9838, 2023). Earth Sciences teaching should play a primary role in the educational system to train citizens with the geoscientific Literacy in order to make conscientious and sustainable decisions. However, studies have shown that this discipline in the last years has suffered a significant decline in the international and Italian school systems. Therefore, a survey was conducted among a sample of 60 Sicilian high school teachers between April and June 2022, in order to find out how they perceive the quality of Geosciences teaching and what they need to teach this discipline more effectively. The critical aspects in Geosciences teaching emerged from the survey have been summarised in four points: the number of hours devoted to Geosciences; the teachers' specific academic background; teacher training; the didactic-organisational structure of the Geosciences *curriculum*. The results of this survey could contribute: (i) to encourage the use of inductive didactic approaches in order to improve the quality of the teaching-learning process; (ii) to provide foods for thought for the designing of Earth Sciences *curriculum* in the Italian secondary school; (iii) to stimulate a wider educational training offer of Geosciences. Some considerations emerged from the analysis of the questionnaire answers can be generalised to the national situation. Despite the limited extension of the sample, the survey represents a first attempt to focus on the situation of Earth Sciences in Sicilian school and to raise the interest of the academic geological community and the educational authorities for the point of view of teachers.

Key words: Geosciences, Survey, Teachers, Upper Secondary School, Effective Teaching.

Riassunto: Barone A., Rotigliano E., Madonia G., *La percezione degli insegnanti sull'efficacia dell'insegnamento delle Geoscienze nella scuola secondaria superiore italiana.* (IT ISSN 0391-9838, 2023). L'insegnamento delle Scienze della Terra dovrebbe avere un ruolo primario nel sistema educativo per formare cittadini che posseggano la *literacy* in Geoscienze necessaria per prendere decisioni consapevoli e sostenibili. Tuttavia, alcuni studi hanno dimostrato che negli ultimi anni questa disciplina ha subito un significativo declino nei sistemi scolastici internazionali e italiani. Pertanto, tra aprile e giugno 2022 è stata condotta un'indagine su un campione di 60 insegnanti delle scuole superiori siciliane, al fine di scoprire come i docenti percepiscono la qualità dell'insegnamento delle Geoscienze e di cosa hanno bisogno per trattare questa disciplina in modo più efficace. Le criticità nell'insegnamento delle Geoscienze emerse dal sondaggio sono state riassunte in quattro punti: il numero di ore dedicate alle Geoscienze; il *background* accademico specifico degli insegnanti; la formazione dei docenti; la struttura didattico-organizzativa del *curriculum* di Geoscienze. I risultati di questa indagine potrebbero contribuire a: (i) incoraggiare l'uso di approcci didattici induttivi per migliorare la qualità del processo di insegnamento-apprendimento; (ii) fornire spunti di riflessione per la progettazione del *curriculum* di Scienze della Terra nella scuola secondaria italiana; (iii) stimolare una più ampia offerta formativa per le Geoscienze. Alcune considerazioni emerse dall'analisi delle risposte al questionario possono essere generalizzate alla situazione nazionale. Nonostante la limitata estensione del campione, l'indagine rappresenta un primo tentativo di mettere a fuoco la situazione delle Scienze della Terra nella scuola siciliana e di suscitare l'interesse della comunità geologica accademica e delle autorità scolastiche nei confronti del punto di vista degli insegnanti.

Termini chiave: Geoscienze, Sondaggio, Insegnanti, Scuola Secondaria Superiore, Insegnamento efficace.

INTRODUCTION

In Europe, studies in the field of Science Education have shown a growing disinterest in science among young people, which has led to a decrease in enrolments in university science majors (OECD, 2006; European Commission, 2007). This situation, over time, could have negative consequences on the quality of European scientific research and its innovation ability (Scapellato, 2017). The Italian educational system is not exempt from this negative trend, especially in Earth Sciences, where the number of students enrolled in Geological Sciences courses has decreased over the last 20 years. In addition, it is recorded that few students choose a career in teaching, because

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they are often influenced by the way professional geologists and geoscientists view the teaching profession (Bonaccorsi *et al.*, 2020).

It is necessary to train young people with appropriate scientific and technological knowledge (European Commission, 2007), in order to develop the European key competences for lifelong learning (European Parliament - Council of the EU, 2006; Council of the EU, 2018). This is particularly relevant in the geological field in order to respond to the environmental emergencies of our time and to form an active as well as responsible citizenship in making conscious and sustainable decisions regarding the Earth and its resources (Wysession *et al.*, 2010; Council of the EU, 2018). Geosciences, indeed, are the disciplines that give fundamental contribution to understanding the functioning of our planet and the impact of the human species on Earth systems, and to solving environmental problems. In particular, specific literacy skills in the Geosciences have an enormous impact on many aspects of our society, including the economy, government policy, health, etc. (Lonsbury and Ellis, 2002; Vanderlinden, 2007). Despite this, there is an evident gap between the relevance and importance of Geosciences in society, especially in the formation of a responsible citizenship, and the scarce attention given to them by the political and educational authorities and in schools around the world (Gill, 2017; Orion, 2017). In this regard, we found the same datum through several discussions with teachers' sample of Natural Sciences in Sicilian secondary schools. It is therefore reasonable to assume that, in many cases, the Geosciences are not given the same dignity and the same space as other scientific disciplines because of the unofficial decisions of many teachers.

The Sustainable Development Goals (SDGs) of the 2030 Agenda highlight important role of education systems to address the challenges of the 21st century, which is why a specific goal is dedicated to education (Goal 4: *Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all*) and is considered a critical tool to pursue all the other goals (Bachiorri, 2020). To underline the importance that Europe confers to the quality of education and environmental issues, the European Commission has formulated: i) the *Key Actions* in support of the 2030 Agenda, to implement the realisation of Goal 4 (European Commission, 2015); ii) the *Agenda for Skills for Europe*, whose goal is the development of skills, considered as a fundamental process to increase the competitiveness and growth of countries (European Commission, 2016). The Geosciences play an important role in making a contribution to many areas of sustainable development. Gill (2017) identifies eleven key aspects of Geology (Agrogeology, Climate Change, Energy, Engineering Geology, Geohazards, Geoheritage and Geotourism, Hydrogeology and Contaminant Geology, Minerals and Rock Materials, Education, Capacity Building and Miscellaneous category) that can contribute to the achievement of the SDGs.

The Italian school system wanted to respond to the necessity of change and innovation in the European and International educational sphere by the Secondary School Reform (Presidential Decree 87, 88 and 89/2010; Ministerial Decree 07/10/2010 no. 211; Directives no. 57 and 65/2010; Directives no. 4 and 5/2012), which has marked the transition from the didactics of knowledge to the didactics of competences. This framework has also simplified the incorporation of the objectives of the 2030 Agenda for Sustainable Development into school curricula, particularly by introducing the transversal teaching of civic education (Annex to Legislative Decree 226/2005; Ministerial Decree no. 35 of 22/06/2020; Law 92/19).

However, recent studies on the Italian Geosciences education system have highlighted some critical aspects, such as a bad organisation and integration of Earth Sciences topics in high school Natural Sciences curricula, the lack of specific guidelines on how the curricula of Natural Sciences sub-disciplines (Earth Sciences, Biology and Chemistry) have to be implemented, the low number of teachers with geological background, low number of weekly hours for Natural Sciences teaching and the reduced practical activities in laboratory and in fieldwork (Realdon *et al.*, 2016; Bonaccorsi *et al.*, 2020). In the light of these considerations we believe the Natural Sciences pedagogical-didactic framework set by the Secondary School Reform does not allow the implementation and realisation of the its own aims and objectives.

Therefore, it is important to understand what the Italian school system needs in order to adequately develop the skills to achieve literacy in Earth Sciences and to pursue effectively the Goal 4 of the 2030 Agenda.

This article investigates Natural Science teachers' perceptions on Geosciences, in particular how the teachers perceive the quality of their teaching, and what they need to make the teaching-learning process in this subject area easier and more effective.

To this end, a survey was carried out on a pilot group of 60 secondary school teachers in Sicily, with the aim of extending it first to a regional and then to a national context.

The results of this questionnaire could contribute: (i) to implement didactic methodologies aimed at improving the quality of the teaching-learning process of Earth Sciences; (ii) to provide foods for thought on the setting of Earth Sciences curriculum in Italian secondary schools, based on the needs expressed by teachers; (iii) to stimulate a wider educational offer of Earth Sciences, taking into account both the necessity and the preferences of teachers and the European and International educational guidelines, in relation to Agenda 2030.

METHODS

We have administered a survey to a pilot group of teachers in upper secondary school in order to understand their point of view on Earth Sciences teaching.

For this purpose it has been structured an anonymous on-line questionnaire which has been divided into 3 sections:

- First section acquires general information about teachers to identify their academic background, working context and years of teaching experience.
- Second section concerns reflection on the quality of teaching in the Geosciences. Teachers were asked to think on: how they evaluate their own didactic action in this discipline; the results obtained with students in terms of knowledge, skills and specific competences; the curricular organisation of the matter during the years of high school; the implementation of some didactic aspects that we consider to be essential to test the quality of teaching, such as the use of inductive approach and specific didactic methodologies, the numbers and type of laboratory and field activities carried out on average per school year. These choices were made on the basis of epistemological aspects of Geosciences (Kastens *et al.*, 2009; Manduca and Kastens, 2012; Irzik and Nola, 2014; Dagher and Erduran, 2016; Rivet, 2017; Occhipinti, 2013, 2019) and some didactic principles for an effective Geosciences teaching (European Commission, 2007; King, 2008; Realdon *et al.*, 2016; Orion, 2017; Scapellato, 2017; Occhipinti, 2019; Bonaccorsi, 2020 etc.). In addition, discussions have been held between the authors and some Natural Sciences teachers in order to get a clearer overview of the subject.
- Third section is dedicated to the needs of teachers in order to improve the teaching-learning process in Geosciences, focusing on four aspects concerning: disciplinary knowledge and competences; the school context in terms of organisation, means and tools available; specific periodic updating; the characteristics of didactic materials that teachers desire.

Closed-ended questions were used for each section, with the exception of the First Section, where also some open-ended short answer questions occur. For some questions, where it was necessary, more than one choice was allowed in order to obtain as many detailed responses as possible and to identify the preferences that teachers consider most significant.

The questions are structured according to: the type of information expected; the review of similar surveys (Rocco, 2014; Realdon *et al.*, 2016; Maraffi and Sacerdoti, 2018); the discussions among the authors and with some school teachers.

With the aim of spreading the questionnaire, a Google form was prepared and sent to upper secondary school teachers in April 2022. Different channels of dissemination were used, such as social media, e-mails to school institutions and to the Palermo section of the *Associazione Nazionale Insegnanti di Scienze Naturali* (ANISN). At this stage, the questionnaire was distributed without selection of schools to obtain as many responses as possible. After three months, the Google form was closed and the data was collected and analysed. On bases of the results, the survey will be extended to a regional and then a national context in a second phase.

RESULTS

The questionnaire was carried out by a sample of 60 high school teachers in Sicily. For each section of the survey, the results are analysed as follows.

First Section – General information

90% of the sample teach in Palermo and province, while the remaining 10% work in other areas of Sicily. Furthermore, 56.6% of the teachers teach in Scientific Lyceum (traditional, OSA, sports), 26.7% in other lyceums (Classical, Linguistic, Human Sciences), 15% in Technical Institutes and 1.7% in Vocational Institutes (fig. 1a). The majority of teachers derive from a biological academic training. These data are consistent with other studies based on a national sample (King, 2013; Realdon *et al.*, 2016; Occhipinti, 2019). Teachers in our sample with biological academic training teach mainly in Lyceums (Scientific Lyceums 69.2%, other lyceums 71.4%). Teachers in Technical and Vocational Institutes (16.7%), come primarily from geological and agricultural fields (42.9% and 28.6% respectively) (fig. 1b). The sample is balanced enough in terms of teaching experience because each working age range is well represented, except for the category with minor years of teaching (fig. 1c). Just over half of teachers have at least 20 years of professional experience. The survey shows that the majority of teachers carry out the Natural Sciences teaching activity from the first year to the fifth year, but in some cases there are partial combinations of pathways (for example first biennium and fifth year or first year and second biennium etc.; fig. 1d). The "first two years" category (31.7% of the sample) also includes all teachers in Technical and Vocational Institutes as is stated in the Italian ministerial documents (table 1; DPR 87, 88 e 89/2010). 58.3% of the teachers claimed that the average number of students per class was around 20-25; 35% of the teachers reported that this number was between 15 and 20 pupils (fig. 1e).

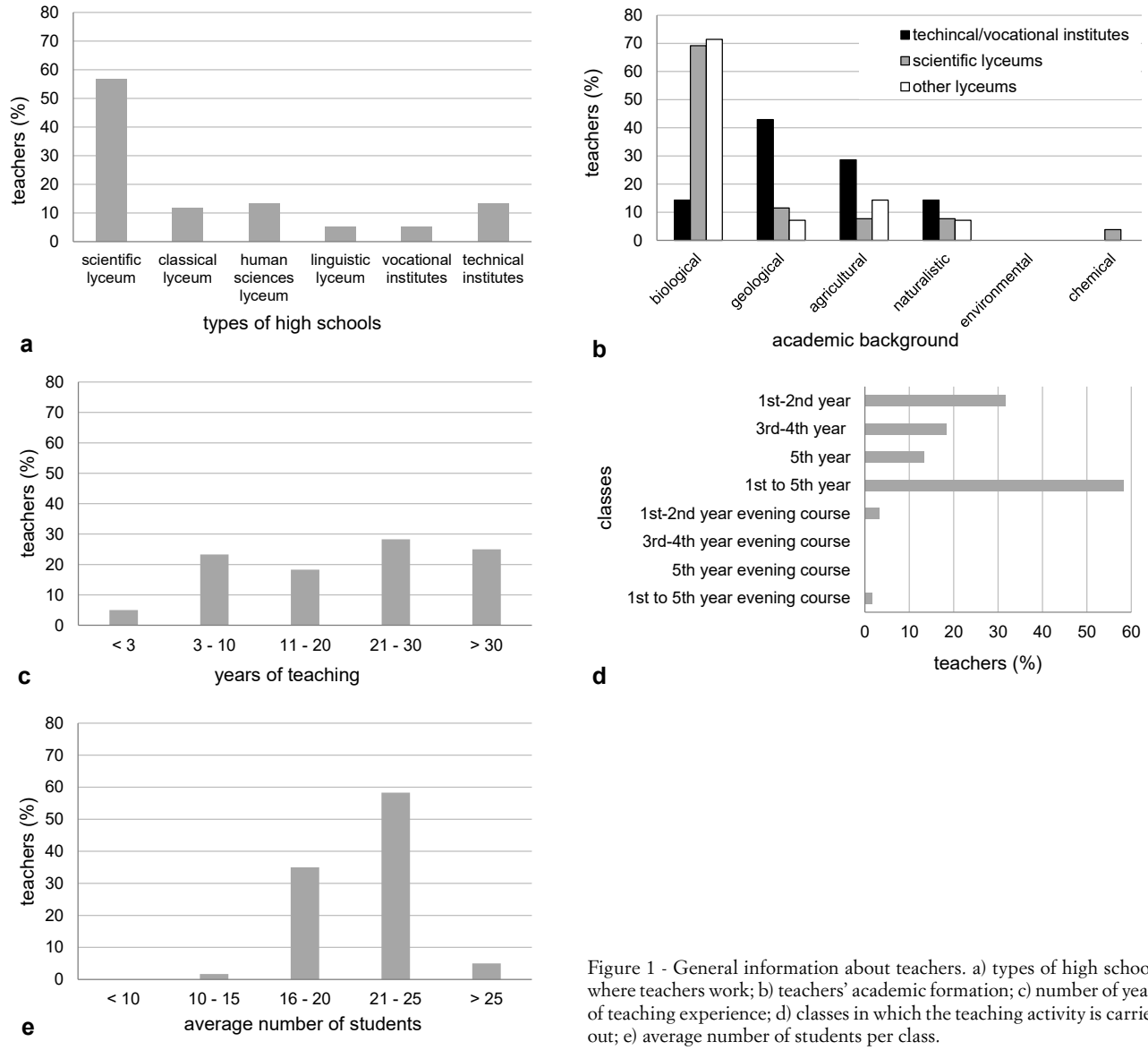

Figure 1 - General information about teachers. a) types of high schools where teachers work; b) teachers' academic formation; c) number of years of teaching experience; d) classes in which the teaching activity is carried out; e) average number of students per class.

Table 1. Weekly timetables of Natural Sciences for the different addresses of upper secondary schools according to the Italian secondary school reform (DPR 87, 88 e 89/2010). (1) Classical, Linguistic and Human Sciences; (2) Music and Dance high school, Human Sciences "Socio-Economic" option, Art School "Figurative Arts", "Architecture and Environment", "Design" and "Scenography", "Audiovisual and Multimedia" and "Graphic Design" options; (3) Art School "Audiovisual and Multimedia" and "Graphic Design" options in which the Natural Sciences hours are also scheduled for the second two-years period.

Year(s)	Traditional Scientific Lyceum	Scientific Lyceum Applied Sciences option	Scientific Lyceum Sports option	Lyceums (1)	Technical Institutes/ Lyceums (2)	Vocational Institutes
1st year (age 14)	2 hours	3 hours	3 hours	2 hours	2 hours	2 hours
2nd year (age 15)	2 hours	4 hours	3 hours	2 hours	2 hours	2 hours
3rd year (age 16)	3 hours	5 hours	3 hours	2 hours	2 hours (3)	
4th year (age 17)	3 hours	5 hours	3 hours	2 hours	2 hours (3)	
5th year (age 18)	3 hours	5 hours	3 hours	2 hours		

Second Section – Reflection on the quality of teaching in the Geosciences

By means of the questions in this section, the teachers carried out a metacognitive process about their didactic action in the field of Geosciences, focusing on some important points regarding the quality of the teaching and the results obtained.

Forty teachers (66.7%) declared themselves satisfied enough (level of satisfaction: fairly high) with their didactic skills in Earth Sciences teaching, only a very small percentage considered themselves to be dissatisfied (fig. 2a). In this context, it was examined whether there is a relationship between the level of satisfaction in teaching Geosciences and the academic background of the teachers (fig. 2b). The results show that the highest percentages for each type of background fall into the "fairly high" category, except for chemists and naturalists who claim to have a "low" and "high" level of satisfaction respectively. It is interesting to note the high percentage of geologists (57.1%) who are not completely satisfied with their didactic skills in Earth Sciences teaching.

We have specifically analysed some of the data taking into account the diversity of the educational pathways in which the teachers work, because these pathways could have an influence on the results. Therefore, school addresses have been split in three main categories: 1. Technical and Vocational Institutes; 2. Scientific Lyceums; 3. other lyceums (Classical, Linguistic, Human Sciences), on the basis of homogeneity of objectives, aim and framework of the Earth Sciences curricula, according to the Italian secondary school Reform (DPR 87, 88 e 89/2010; DM 07/10/2010 n. 211; Direttive N. 57 e 65/2010; Direttive N. 4 e 5/2012).

One requested question was to identify the main difficulties of the students in learning Geosciences in terms of knowledge, skills and competences (fig. 2c). In Technical and Vocational Institutes, the main difficulties are in competences and knowledge, while in all lyceums, they are in knowledge, skills and competences. Only 4.8% of the whole sample of teachers affirm not to recognise difficulties with their students.

We thought it was necessary to focus on the number of hours actually dedicated to this discipline per school year in order to determine the didactic continuity and the level of in-depth teaching of the Earth Sciences. In Technical and Vocational Institutes Geosciences are only taught in the first biennium (table 1; DPR 87, 88 e 89/2010) and teachers interviewed treat Earth Sciences topics only in the first year. For this reason, we focused only on lyceums where Earth Sciences are set for at least two hours per week for the whole quinquennium. Depending on the particular course option of the lyceums the number of hours dedicated to this subject vary. So, also in this case, the results have been identified on the basis of the specific lyceum course option. They are divided into Scientific Lyceums, which have a higher number of hours, and other lyceums (Classical, Linguistic, Human Sciences) where two hours per week are set (table 1; DPR 87, 88 e 89/2010).

As shown in figs 2d and 2e, the number of hours per school year devoted to Geosciences is not constant regardless of the school addresses. In particular, in the second year, a large number of teachers do not dedicate a single hour to Earth Sciences (35.3% Scientific Lyceums and 37.5% other lyceums). The first year, on the contrary, has a distribution shifted toward the higher percentages: 29.4% of teachers in Scientific Lyceums devote between 50% and 70% of the curricular hours to Geosciences; in the other lyceums, the percentage remains at high values, because 43.7% of the teachers dedicate half of the curricular hours to Earth Sciences. Substantially, there are analogous trends in the two sub-samples, but with some differences in the percentages of devoted hours.

At this point, in order to verify the quality of teaching in the Earth Sciences, we have taken into account six didactic aspects to evaluate the effectiveness of teaching-learning process, namely: the use of deductive approach and specific didactic methodologies, the numbers and type of laboratory and field activities carried out on average per school year (figs 3a, 3b and 3c).

Regarding to the first aspect, the majority of the teachers in Scientific Lyceums (81.25%) and Technical and Vocational Institutes (64.70%) almost always adopt a traditional approach to teaching Geosciences (the percentage of use remains between 40%-60% and >60%), while in other lyceums 50% of teachers use the deductive approach (fig. 3a). Fig. 3b shows that teachers know participatory teaching (PT) and problem posing (PP), multimedia lesson (didactic videos, interactive exercises etc.), laboratory activities and/or in group activities and the Flipped Classroom. These are the inductive methodologies used by most of teachers in the teaching of Earth Sciences, regardless of the type of school address (fig. 3c). Although other more innovative methodologies, such as Inquiry Based Science Education (IBSE), Problem Based Learning (PBL), Debate and Storytelling, are known well enough they are used very little.

The number and type of laboratory activities and field trips represent a fundamental part to the development of the learning process in Geosciences and the achievement of specific competences. Data highlight that the majority of teachers in Technical and Vocational Institutes and other lyceums usually conduct between 3 and 5 laboratory activities per school year. On the other hand, 44.1% of teachers in Scientific Lyceums carry out less than 3 laboratory activities and 52.9% between 3 and 10 (fig. 4a).

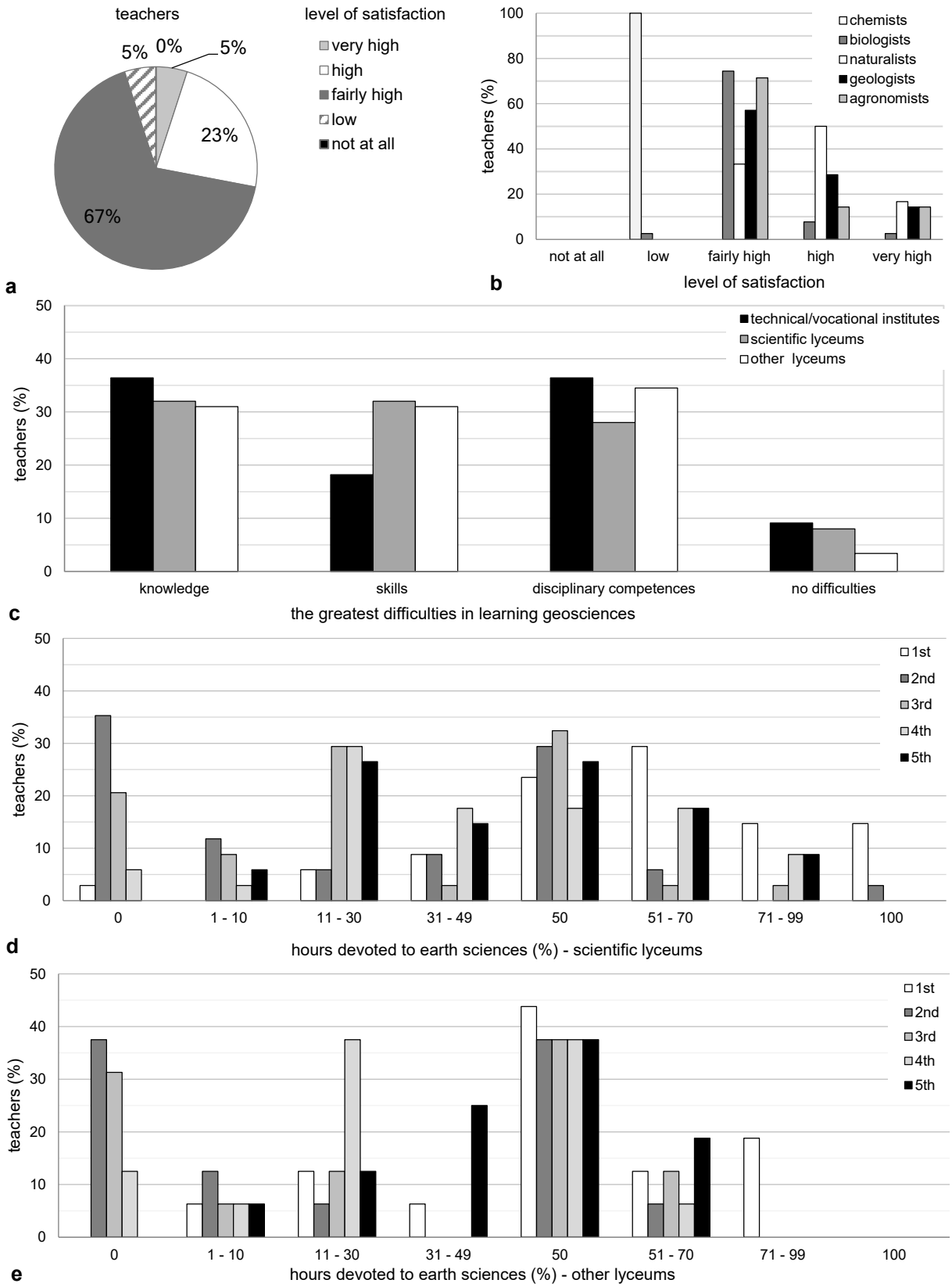

Figure 2 - Reflection on the quality of teaching in the Geosciences. a) level of satisfaction with didactic skills in Geoscience teaching; b) the relationship between the level of satisfaction in teaching Geosciences and the academic background of the teachers; c) the main difficulties of the students in learning Earth Sciences; d) percentage of hours per school year devoted to Geosciences in Scientific Lyceums; e) percentage of hours per school year devoted to Geosciences in other lyceums.

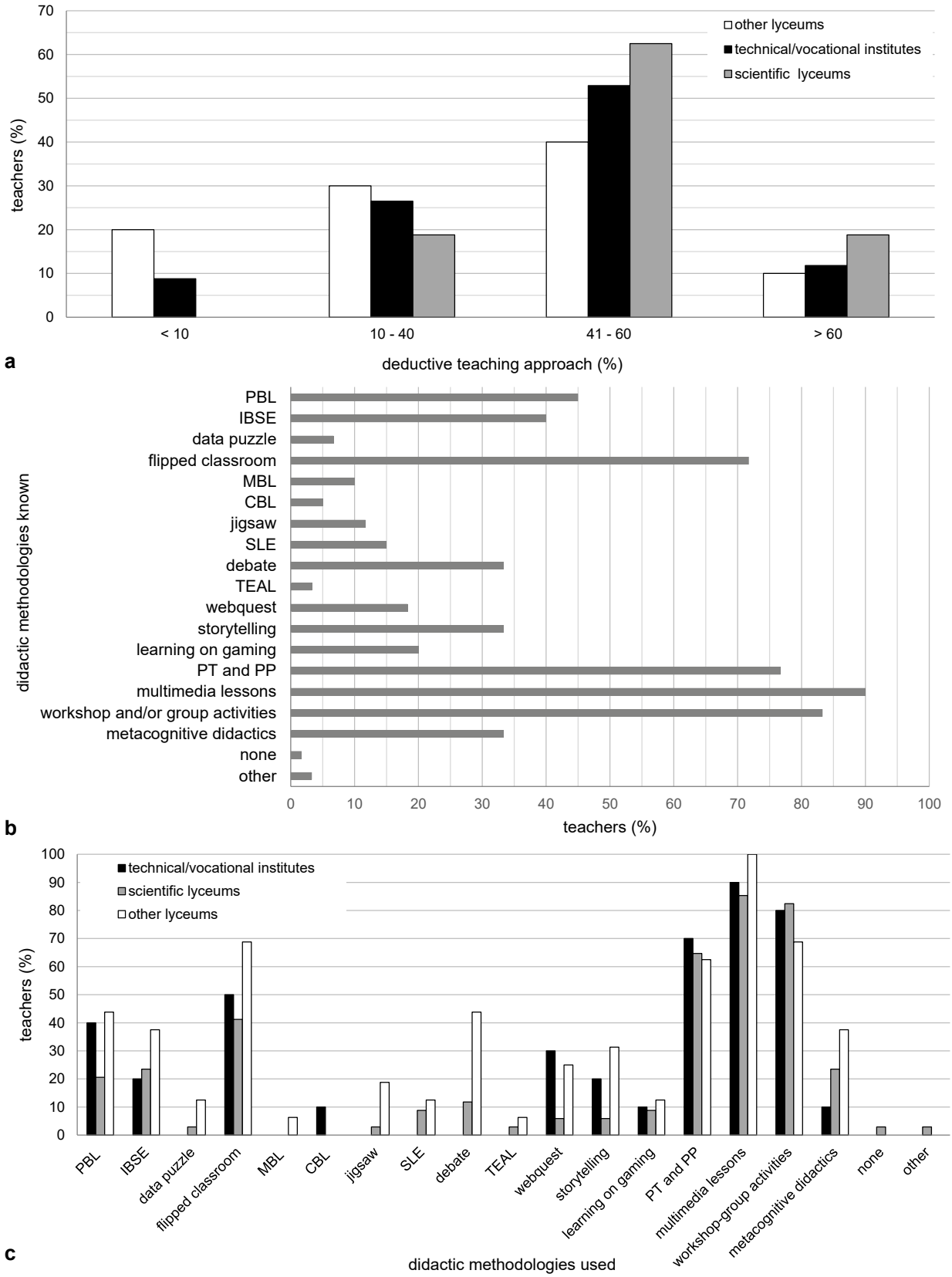

Figure 3 - Teaching approach and didactic methodologies. a) percentage of deductive (traditional) teaching approach; b) specific didactic methodologies known (CBL: Challenge Based Learning; SLE: Situated Learning Episodes; TEAL: Technology Enhanced Active Learning); c) specific didactic methodologies used (other: nature walks in the style of Socrates and Platon; segmented lesson).

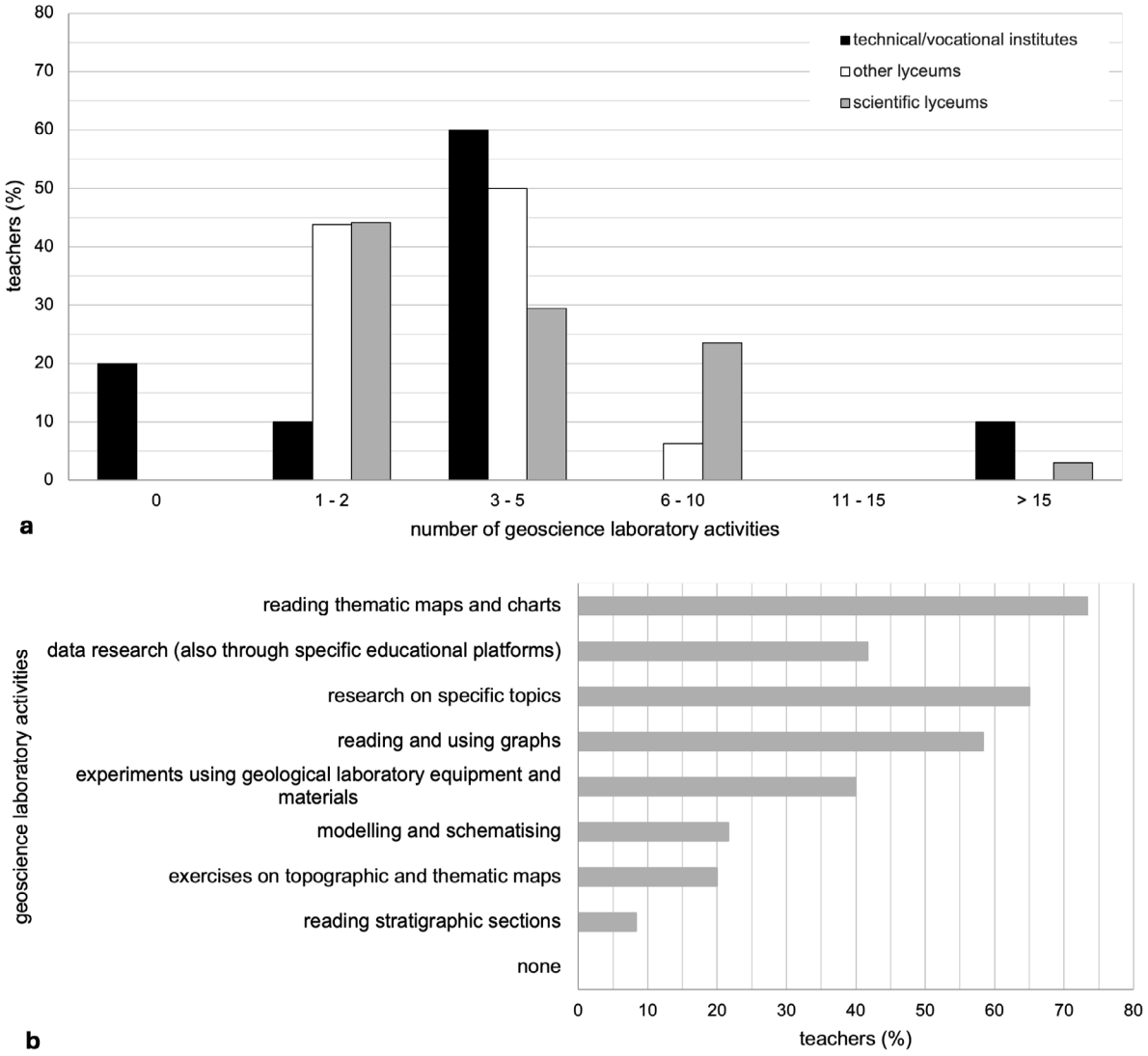

Figure 4 - Laboratory activities. a) number of Geoscience laboratory activities per school year; b) types of Geoscience laboratory activities carried out on average per school year.

The type of activities is focused especially on the reading charts and thematic maps (73.3%). Unfortunately, these activities are not matched with exercises on the scales, calculations of altitude and geographical coordinates, construction of altimetric profiles etc. (carried out by only 20% of the teachers) (fig. 4b). This thing reduces the didactic potential of the thematic maps in Geosciences. More than half of the teachers propose to students research information about specific topics (65%), reading and using graphics (58.3%), while 41.7% make students carry out research through specific didactic platforms.

The number of educational trips per school year is rather scarce in this discipline that is based on field work and has as objective the study of the natural environment, from which observations, hypotheses, models and predictions are made. Fig. 5a shows that 50% of the teachers in Technical and Vocational Institutes implement two educational trips per year, but the distribution shifted toward lower frequency classes. The majority of teachers in Scientific Lyceums and other lyceums carry out only one educational trip, but the distribution shifted towards higher frequency classes for the scientific lyceum.

In the end, the typology of these educational trips is mainly focused on visits to museums (76.7%), natural reserves (70%) and *pathways for the acquisition of transversal competences and for orientation* (PCTO) at universities, research centres, specific sector companies, protected areas managed governmental and non-governmental entities etc. (25%) (fig. 5b). It is interesting to note that most teachers implement educational trips preferably in protected areas (reserves, parks, SIC etc.), giving an ecological-naturalistic perspective to the activities. Only 23.3% carry out typical guided geological excursions (study of relevant geological outcrops or structures, geosites, landforms, karst cavities,

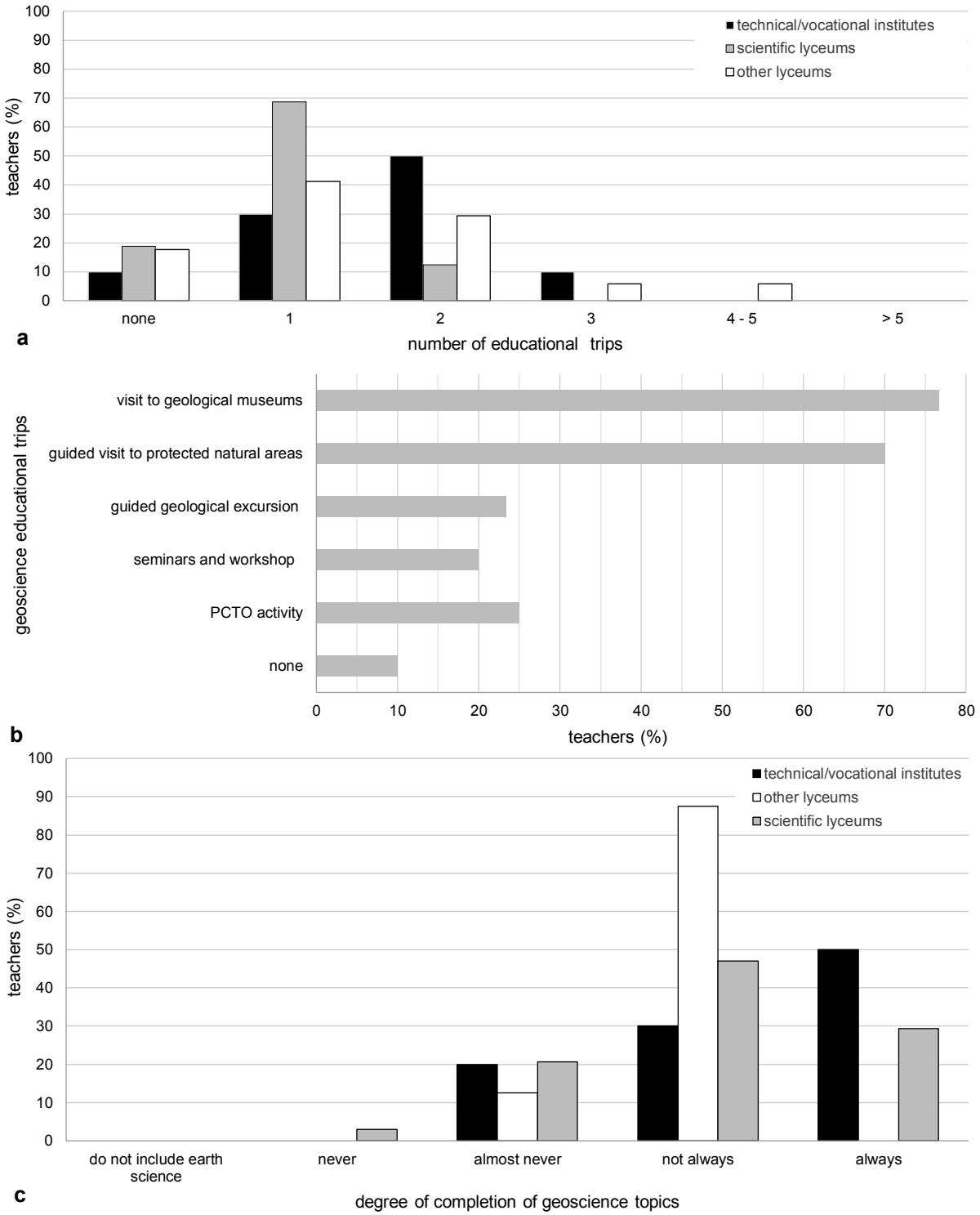

Figure 5 - Educational trips and topics. a) number of educational trips on average per school year; b) types of Geosciences educational trips; c) degree of completion of topics set out in their didactic plan and according to ministerial guidelines.

volcanoes, etc.) which have a fundamental didactic value in developing the Geosciences competences.

Finally, teachers have been asked if they normally manage to discuss all the topics in their didactic plan and according to ministerial guidelines. The data shows that half of the teachers in Technical and Vocational Institutes manage to address all the topics in the school programs. However, the majority of teachers in Scientific Lyceums and other lyceums do not always complete all of the topics (fig. 5c).

Third Section – Teachers' Needs

In the last section, three questions were set with a maximum number of options (see figs 6b, 8a and 8b) in order to avoid scattering the data and to better focus on the more meaningful preferences. The first question aims to make the teachers conscious of their didactic skills.

Almost half of teachers (43.3%) think of having adequate didactic skills and only 18.3% a little bit adequate (fig. 6a). The choice of the intermediate option "fairly high" indicates that they are not completely satisfied with their didactic competences to make their students acquire the Earth Sciences Literacy skills.

In this way, the teachers have been asked what they consider to be important to make their didactic action in the Earth Sciences effective. In this regard, we have focused first on the sphere of disciplinary knowledge and competences, then on the school setting such as organisation, means and tools available, periodic specific training and characteristics of didactic materials for the students.

On the first aspect, the majority of the sample chose the "didactic competences" (methodologies, activities, didactic materials etc.), "competences in the use of specific laboratory tools" and the "deepened knowledge of topics" (fig. 6b). Instead, the options "knowledge of the Nature of Geosciences" and "competences in geoscientific investigation methods" were given little attention by the teachers. These aspects should have more importance because they provide an understanding of how geoscientific knowledge is built up and can be acquired.

Next, we have analysed the second aspect that is important to make the didactic action more effective, using the teachers' competences in a coherent and meaningful way. In this case, the majority of the choices are focused on six options which should need to be improved (fig. 6c): "school organisation", in terms of timetables, spaces, hours of lesson etc.; "planning of outdoor educational activities" in museums, protected areas, geosites etc.; "number of pupils per class" (it should not be more than 20); "equipment availability"; "students' motivation"; "specific teachers training" (training courses, workshops, seminars, webinars).

Regarding to the means and tools used by teachers for their training, the majority of the sample usually devotes to self-training through "consultation and sharing of materials on the web", "reading journals and publications in the field" and "attending conferences, seminars and webinars" which need less commitment in terms of hourly and workload than courses and workshops. Furthermore, half of the teachers affirm to use also "visits to museums, natural parks, geosites etc," as training (fig. 7a). In particular, in the school year 2021/2022, teachers' preferences have remained almost the same. Only a decrease of the percentages for each option is noted, but with a coherent trend. Finally, a notable decrease in "attending conferences, seminars and webinars" it is evident, probably due to the pandemic situation we lived in.

Teachers have been asked when was last time they had taken a training course/workshop in Earth Sciences (fig. 7b): 38.4% of teachers had taken one in the last two years ("this school year" and "last school year"); 23.4% between two and four years ago ("two years old" and "two to four years ago"); 20% in more than four years ago; and 18.3% had never took anyone. This means that 61.7% of the sample have a formation older than two years or do not have one yet. In order to deepen the analyse, we considered the sub sample of 61.7% and we investigated whether there is a correlation between Geosciences training and both teachers' Geosciences background (fig. 7c) and years of teaching (fig. 7d). In the first case, the type of academic formation is not significant, as all percentages are above 60%, with few differences between them, except for geoscientists percentage (57.1%) that is slightly lower than the others. In the second one, the years of teaching seem to have an influence on the teachers' training: the highest percentages of teachers who have the oldest or no training in Geosciences fall in the 20-30 and >30 years of teaching classes (32.4% and 24.3% respectively).

In order to make teachers' training effective, to their needs and perspectives, we believe it is necessary to first understand if they are willing to attend training courses/workshops in Geosciences. In this respect, almost all of the teachers would be interested in attending a training course/workshop in this field, but half of them would only attend if the topic was to their liking. The topics/activities preferred by teachers are (fig. 8a): "experimentation of laboratory activities", "experimentation of field activities" and "experimentation of new didactic methodologies". Also in this case, some fundamental aspects are overlooked, such as "in-depth analysis of Nature of Geosciences" and "in-depth analysis of investigation methods typical of Geosciences".

Finally, the characteristics that the didactic materials should have in order to be effective and useful have been identified in three categories (fig. 8b): "structured" (with teacher's guide and material for essay and evaluation), "innovative", and "user friendly". Data could be used in the future to structure training courses/workshops in Geosciences according to these needs and preferences. This could make the training more effective and engaging for the teachers.

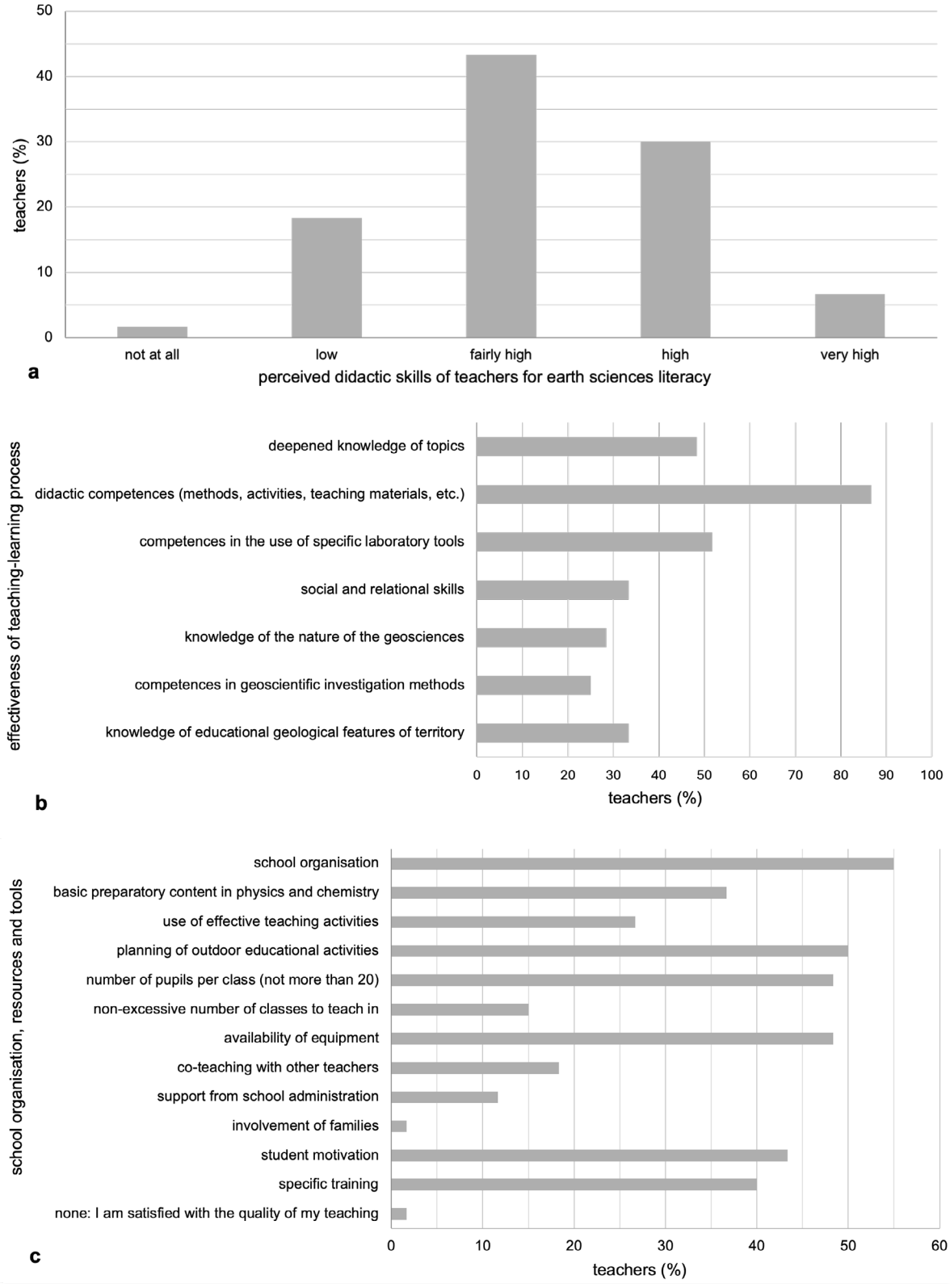

Figure 6 - Teachers' needs. a) perceived didactic skills of teachers in the field of Geoscience in order for their students to acquire Earth Sciences Literacy competences; b) what is important to teachers for an effective teaching-learning process (max 3 choice options); c) school organisation, resources and tools that teachers consider necessary to improve their teaching of Earth Science (school organisation: timetables, places, number of lessons per week, etc.; planning of outdoor educational activities: in museums, protected areas, geosites, etc; specific training for teachers: refresher courses, workshops, seminars, webinars).

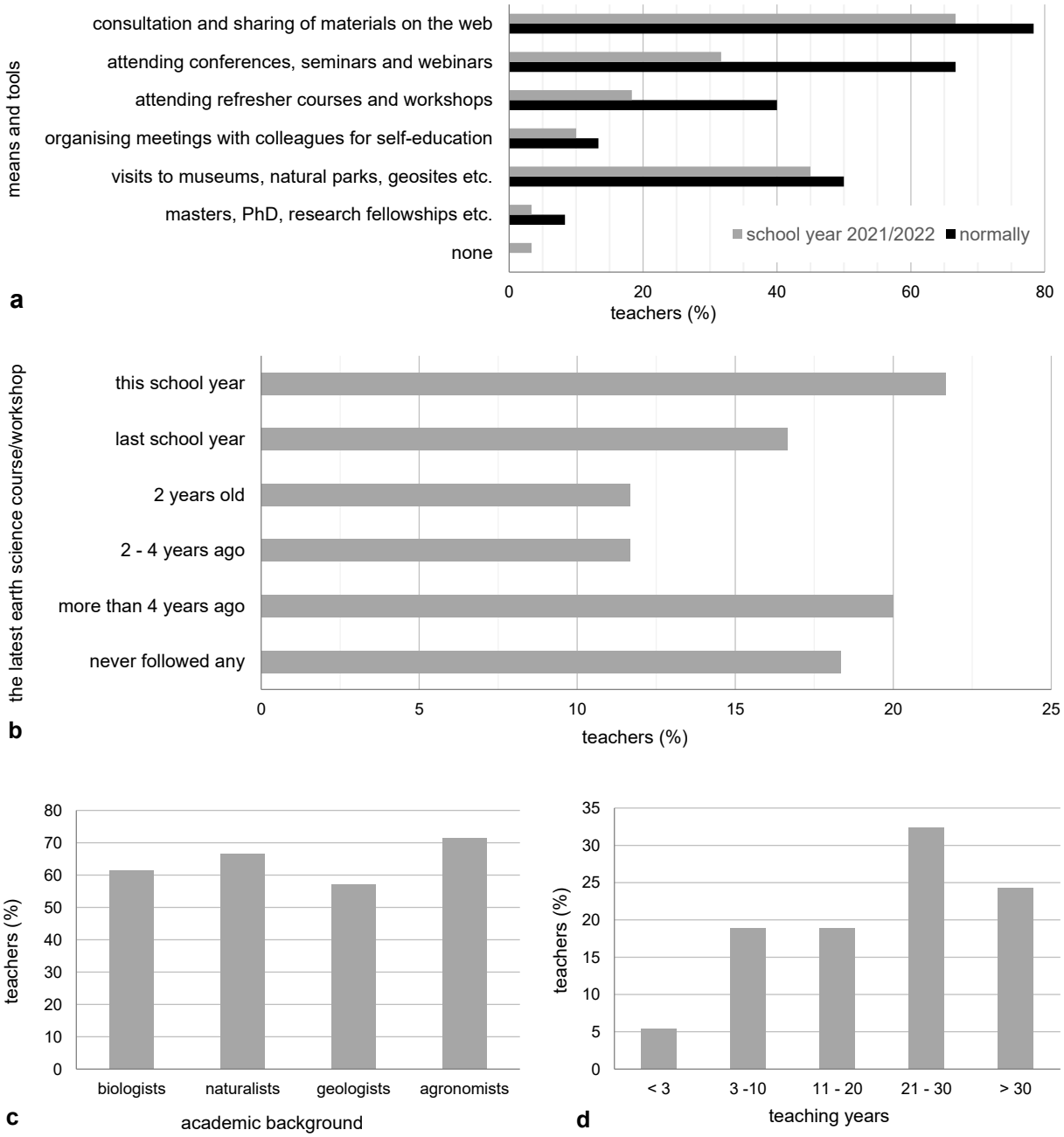

Figure 7 - Teachers' training. a) means and tools used by teachers for their training in the field of Earth Sciences, normally and in the school year 2021-2022; b) the latest Earth Science refresher course/workshop attended by teachers; c) teachers formation older than two years or do not have one yet related to their academic background; d) teachers formation older than two years or do not have one yet related to the teaching years.

DISCUSSION

From the survey it can be deduced that teachers' sample recognizes some critical issues in the Geosciences teaching that are translated into unsatisfactory levels of knowledge, ability, disciplinary (fig. 2b) and Geosciences Literacy competences among students (fig. 6a). In this study different aspects contributing to the problem of learning Geosciences for pupils, have been identified and summarised as reported below.

The number of hours actually devoted to Earth Science

According to the ministerial documents (DPR 87, 88 e 89/2010; DM 07/10/2010 N. 211; Directive N. 57 e 65/2010; Directive N. 4 e 5/2012), the topics of Earth Sciences are treated together with those of Biology and Chemistry within the teaching of Natural Sciences (table 2).

As a consequence less than half of the total curriculum hours for each year are devoted to Geosciences, as the survey also shows. Especially in the second year, the data

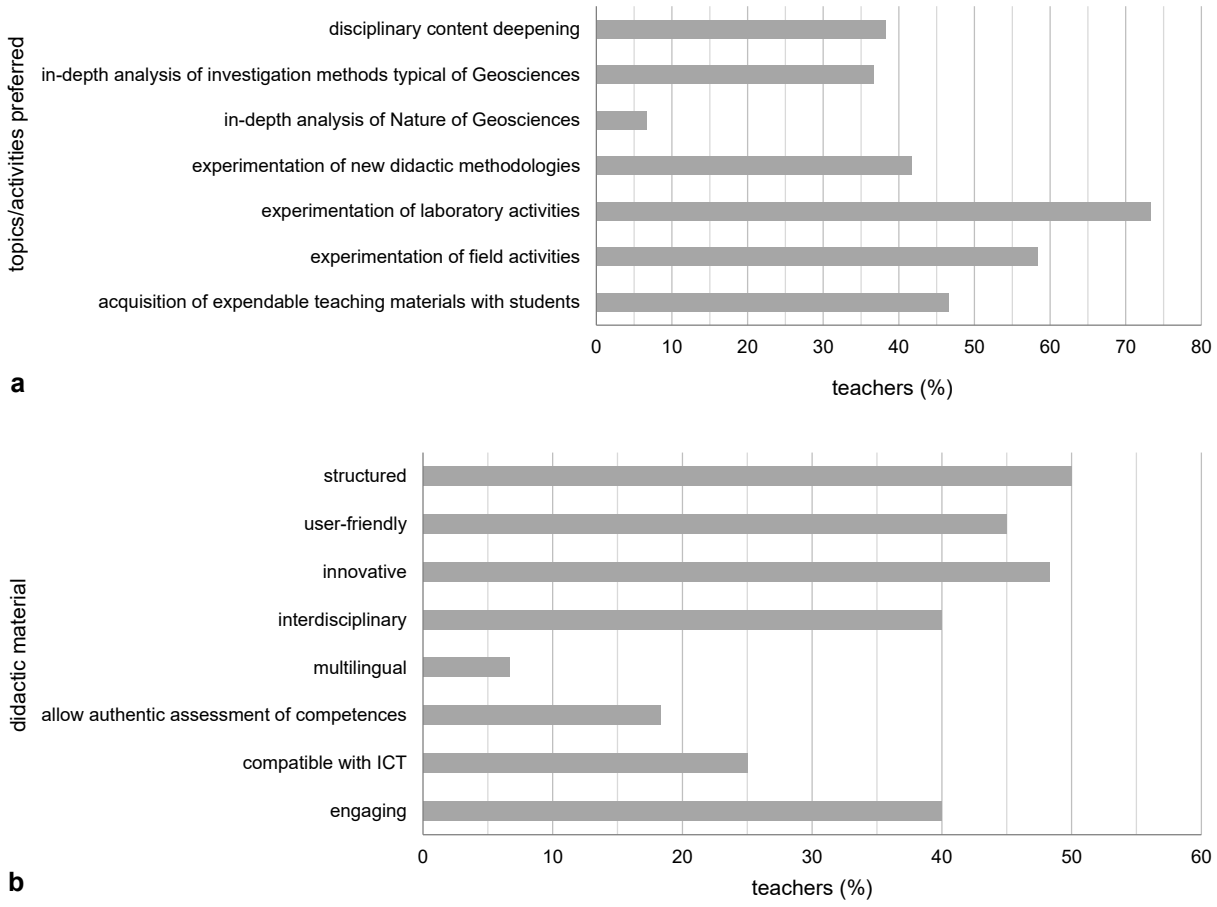

Figure 8 - Refresher course/workshop features. a) topics/activities preferred by teachers to be covered in a refresher course/workshop in Earth Science (4 options to choose from); b) characteristics of the didactic material in order to be effective and useful (ICT: Information and Communication Technologies).

indicate that there is an increase in the number of teachers who do not treat this subject in order to give more space to the other Natural Sciences subjects. This is because Geosciences are taught in the first year of the first biennium, in accordance with ministerial guidelines (figs 2d, 2e). The survey shows that the majority of sample teachers in Lyceums and half of the ones in Technical and Vocational Institutes do not always complete all of the Earth Sciences topics (fig. 5c). It is likely that the better data for Technical and Vocational Institutes are because teachers organise the Natural Sciences subjects more effectively, planning the Earth Science topics in only one year. Moreover, almost the entirety of the interviewed affirm that the most innovative methodologies, such as IBSE, PBL, Debate and Storytelling are used very little (fig. 3b). Since it is necessary to address all the disciplines concerned in the field of Natural Sciences, we believe that the time devoted to Geosciences is not enough to implement an effective didactic in this discipline and to complete the topics planned, as the ministerial guidelines point out (fig. 5c).

From the survey results, the fragmentation and marginality of Earth Sciences curriculum over the five years of the upper secondary schools emerges, as well as the lack of guidelines with chronological separation between the three subjects of Natural Sciences, according to Realdon *et al.*, 2016. Therefore, it would be necessary to increase the number of hours per week and to divide the curricula so as to identify two distinct paths, but strongly interconnected, that is, "Earth and Environmental Sciences" and "Life Sciences and Biotechnologies". In this way, teachers with background in geological field should teach "Earth and Environmental Sciences" and teachers with background in biological field "Life Sciences and Biotechnologies". This would allow to overcome the basic formative gap due to the different academic backgrounds of the teachers, but it would require a new structuring of the Italian pedagogical school system.

The academic background of the teachers

In line with the Italian national context and with literature data (Realdon *et al.*, 2016; Occhipinti, 2019; Bonaccorsi *et al.*, 2020) the survey shows that the academic training of teachers is in most cases in the biological field or in other

Table 2. Earth Science topics in the different addresses of upper secondary schools according to the Italian National Indications and Ministerial Directives (DM 07/10/2010 n. 211; Direttive N. 57 e 65/2010; Direttive N. 4 e 5/2012). (1) Classical, Scientific, Linguistic and Human Sciences; (2) Art School "Audiovisual and Multimedia" and "Graphic Design" options in which the Natural Sciences hours are also scheduled for the second two-years period; (3) Music and Dance high school; Human Sciences "Socio-Economic" option; Art School "Figurative Arts", "Architecture and Environment", "Design" and "Scenography" options.

Year(s)	Lyceums (1)	Lyceums (2)	Technical Institutes / Lyceums (3)	Vocational Institutes
1st and 2nd (age 14-15)	Astronomical Geography Geomorphology Hydrosphere and Cryosphere Atmosphere	Astronomical Geography Geomorphology Hydrosphere and Cryosphere Atmosphere	Astronomical Geography Geomorphology Hydrosphere and Cryosphere Atmosphere Geosphere (minerals and rocks) Earthquakes Volcanoes Orogenesis	Astronomical Geography Geomorphology Hydrosphere and Cryosphere Atmosphere Geosphere (minerals and rocks) Earthquakes Volcanoes Orogenesis
3rd and 4th (age 16-17)	Mineralogy (hints) Petrology (rocks) Earthquakes Volcanoes Orogenetic processes	Geosphere (minerals and rocks) Earthquakes Volcanoes Orogenesis		
5th (age 18)	Meteorological Phenomena Plate Tectonics Interrelationships among: Hydrosphere, Atmosphere, Geosphere In-depth studies on topics chosen from those related to ecology, resources, traditional and renewable energy sources, biogeochemical cycles			

scientific areas that are not geological (fig. 1b). This situation has several consequences that need to be taken into account:

i) the fact that the majority of the teachers, regardless of their academic formation, have chosen the intermediate option "fairly high" to evaluate their didactic skills in the Geosciences (figs 2a, 2b and 6a), indicates that they do not consider themselves fully satisfied and feel the need to improve their competences in this discipline through specific pathway training. This is understandable for teachers without a geological background, but at first sight it might not be for geologists (51.7% fig. 2b). This interesting datum could be due to a lack of adequate educational competences among geologist-teachers, as geological knowledge alone is not enough to make teaching effective.

ii) as highlighted by our survey, the deductive didactic approach is almost always used for the teaching of Geosciences (fig. 3a), although some of the main inquiry methodologies based on inductive approaches are known (figs 3b, 3c). Even though this data should be the object of further studies, it is possible to formulate some preliminary hypotheses: firstly, many teachers by not having a solid geological background find difficulties to implement an inductive didactic in this discipline; secondly, the number of curricular hours established by the Italian ministerial reform for Natural Sciences (DPR 87, 88 e 89/2010; see tables 1 and 2) are not sufficient in order to use the methodologies based on inquiry, which require more time for their development. As a result, the methodological approach to the discipline is inadequate and not very effective in order to acquire the specific skills/competences.

iii) from the data it can be deduced that the didactic and formative value of the laboratory and on field activities has not yet properly understood. Specifically, the laboratory activities conducted by teachers should be carried out regularly throughout the school year while currently they are only carried out once or twice during the school year (fig. 4a). The survey data show that Technical and Vocational Institutes, where more laboratory activities are implemented, have better "skills" results among students, as shown in Figure 2c. The same happens for the field activities, because of both the low number of excursions made during a school year and their typology. These are almost exclusively focused on visits to museums and protected natural areas, characterised by a more ecologic-naturalistic approach (figs 5a, 5b).

iv) the difficulty in completing the Geosciences topics (Fig. 5c) may be due not only to the scarce number of hours per week, but also to the fact that many non-geologist teachers often struggle to identify the complexity of the interrelationships between the Geosciences subdisciplines. According to Occhipinti, 2013 this leads to the

non-identification of indispensable learnings, fundamental concepts and the choice and design of logical pathways in view of the progression of knowledge.

v) an interesting datum is about "student motivation" (fig. 6c), because 43.3% of the teachers' sample think that this is an important feature which needs to be increased. In many cases, the scarce motivation of students for the subject and/or the academic choice in Geosciences stems not only from a traditional teaching approach, but also from how much teachers trigger the passion for this discipline at school. As the majority of teachers do not have a geological background, they often do not have enough interest or passion for the Geosciences (Realdon *et al.*, 2016; Occhipinti, 2019; Bonaccorsi *et al.*, 2020). Indeed, data from a survey carried out on a sample of more than 700 geology students (Greco and Gualtieri, 2010), demonstrated that geologist teachers can make the difference to motivate the career choice of the students.

The disequilibrium in favour of the biological academic formation in our teachers' sample is in line with the national trend (Realdon *et al.*, 2016; Bonaccorsi *et al.*, 2020). This imbalance is partly due to the number of students enrolled in Biological Sciences, which is more than ten times higher than the students enrolled in Geological Sciences (data relating to 2021-2023 years, Ministero dell'Università e della Ricerca), and this means increasing likelihood that more people will choose to teach. In the same time, more biology-teachers lead more students enrol in Biology Sciences, as it is actually observed. Another reason of this situation is due to the fact that among the students of Geosciences relatively few choose to become teachers (Bonaccorsi *et al.*, 2020).

The specificity of modern academic studies is a necessary condition to guarantee the quality of scientific research and to respond adequately to the current problems. However, this specificity becomes a disadvantage in the field of Natural Sciences teaching, because this makes it difficult to implement an effective teaching-learning process for whole disciplines of the Natural Sciences and especially in the Geosciences. Although in the academic Italian system it would be possible to include course studies that allow students to qualify for high school teaching (Bonaccorsi *et al.*, 2020), these are not sufficient to fill the gap for the acquisition of the method, the knowledge and those competences that characterise a geoscientist and represent his/her essence. In our opinion, the training paths should take into account the varied scientific backgrounds of the teachers, in order to structure academic paths that allow to fill the formative gap. These courses should focus not only on the knowledge but also on the epistemic principles of all the disciplines involved and should provide a specific didactic base for the different scientific areas. The in-depth analysis of the didactic-epistemic aspect, as is also stated by Occhipinti (2013), is rather left to the initiative, the time available and the specific skills of the teachers.

The didactic-organisational structuring of the Natural Sciences curriculum in upper secondary school

As deduced from the survey, some aspects of the organisation of the Natural Sciences curriculum and the availability of resources and means in the Sicilian upper secondary schools involved in the interview should be improved. The elements of criticism are due both to the directives of the individual scholastic institute and to the ministerial framework. They have been summarised in the following points (fig. 6c):

- the school timetable, that is often badly distributed over the week (such as always the last hours or hours on two consecutive days, etc);
- the very low number of weekly hours available in order to develop the competences of the whole Natural Sciences corpus in an effective way;
- the very high number of pupils per class, which does not allow for an effective didactic action by the teacher;
- the scarcity of adequately equipped laboratories (such as mineralogical microscopes, thin sections, sediment samples, sieves, topographic maps etc.) in order to carry out specific activities for the Geosciences (in fact, the available resources and means are only useful in the biological and chemistry fields, but rarely in the geological field);
- the lack of adequate spaces and times to implement laboratory and field activities necessary for the development of the geoscientific competences.

A revision of these aspects highlighted by the teachers' sample would facilitate the implementation of the didactic activities and would help stimulate the students' motivation in the field of Geosciences. Regarding the spaces, it is important to provide students with modern and functional learning environments for the laboratorial activities, as well as to give the opportunity to develop a way of learning based on field work, that is a central and formative experience for the Earth Sciences. Although there are many simple experiments available in the literature or on the web that do not require a well-equipped laboratory (e.g.: http:/farelaboratorio.accademiadellescienze.it/; www.earthlearningidea.com etc.), we believe it is important for students to use a scientific laboratory that is equipped not only for biological or chemical activities, but also for geological ones. This may help to put the Earth Sciences on the same level as the other disciplines of the Natural Sciences and make the learning process more effective for students. Regarding the times, there is a need for more lesson hours in order to implement the inductive approach and achieve didactic competences as required by the ministerial documents. In addition, the school timetable should be designed to enable pupils to acquire the new knowledge and skills in an effective way, taking into account a balanced distribution of hours per week and per day.

Teacher training

During the school year 2020-2021, the percentage of interviewed teachers who attended a training course or a workshop in the field of Geosciences was very low and almost 61.7% of the sample should either attend a training course or update their didactic competences (fig. 7b). These results are not dependent on teachers' academic formation (fig. 7c), but years of teaching may play a role. Teachers with more than 20 years of teaching experience have the oldest or no training in Geosciences (fig. 7d), and the reason for this could be a loss of interest in geological subjects or tiredness of doing a very demanding job for so many years. However, in most cases teacher training occurs in the form of self-training and secondarily less demanding activities such as seminars, conferences or webinars (fig. 7a). Probably, this is due to the fact that the workload of teachers often does not allow them to participate productively in professional training.

In response to this situation, the Italian Ministry of Education and Merit should plan training paths when the teachers' workload is lower (e.g.: at the end of in class activities, on June and/or July).

On the other hand, the exclusive modality of self-training can not be resolved to address the difficulties in the field of Geosciences, especially if the majority of the teachers have a non-geological background. In fact, teachers feel the necessity to be supported by effective and engaging Earth Sciences training paths that allow them to experiment in the laboratory and in field activities. In addition, in the survey teachers state they need didactic materials spendable in the classroom with the following characteristics: structured (teacher's guide and materials for assessment and evaluation), innovative and user-friendly (fig. 8b). In these years, many projects and training courses in the Geosciences have been carried out by Universities for teachers at national and local level, such as the "Progetto Lauree Scientifiche" (PLS/PNRR) or the "Progetto Laboratorio di Scienze - Obiettivi Specifici di Apprendimento" (LS-OSA). However, in some training courses, the requested of teachers are not always adequately curated. In fact, these courses often focus mainly on theoretical aspects and/or provide not well-structured or not easily spendable didactic materials.

The survey shows that many teachers think that it is enough to deepen the didactic knowledge and competences and the use of laboratory tools in order to improve Geosciences' teaching-learning process. They neglect fundamental aspects such as knowledge of the Nature of Geosciences, epistemic principles and in depth analysis of the investigation methods (fig. 8a), which are rather lacking, if not completely absent, in the Italian training offer. Probably, the lack of an epistemic background makes teachers feel that they do not have fully sufficient and effective didactic competences for the achievement of the Geosciences Literacy and for the acquisition of an adequate level of knowledge, skills and competences. In addition, it also has to take in account the constitutive difficulties of the discipline, such as its complexity and articulation, which make the teaching-learning process hard. Normally, the main difficulties for the students are due to the fact that the geologic processes are developed in extremely low times and in too much large spaces for reproducing them in classroom (Kastens and Rivet, 2010); the complex phenomena due to interaction among the spheres of the Earth System range from seconds to millions of years and, being difficult to observe, are often neglected or misunderstood (Assaraf and Orion, 2005; Raia, 2008); the cognitive processes and concepts based on temporal and spatial reasoning, so important for a geoscientist, are not easily achieved by each individual. That is the reason why it's necessary to develop and improve them through constant and effective practice (Kastens *et al.*, 2009).

CONCLUSIONS

We believe that education systems play a key role in promoting scientific literacy by proposing and developing inductive and innovative didactic approaches that are better suited to attracting interest and holding responsible students to the environmental challenges of our time. In this sense, the Ministerial Reform of the Italian High School promotes the transition from an almost exclusively deductive instructional approach, which is still deeply rooted in the teaching of scientific disciplines to an inductive and innovative one. The renewal process underway at national and international levels must be translated into a serious pedagogical-didactic reflection in order to structure a coherent and organic way the learning paths. This could lay solid foundations for the training of future geoscientists and students that, from kindergarten to university, are literate in the Geosciences.

However, from the literature studies and from the survey carried out on a pilot group of 60 Sicilian secondary school teachers, some critical issues emerge in the Italian ministerial approach to the educational-didactic system in the field of Natural Sciences and, in particular, of Geosciences. This situation has an impact on the acquisition of knowledge, skills and specific competences by students who do not manage to reach satisfactory levels.

This survey aimed to provide a first insight into the situation of Geosciences in schools from the point of view of teachers in a local context, which in a second phase is going to be extended to a regional and then a national level. From the analysis of the questionnaire results, the critical aspects in the teaching of Earth Sciences have been identified and summarised in four main points:

– the number of hours actually devoted to Earth Science.
– the academic background of the teachers.

– the didactic-organisational structuring of the Natural Sciences curriculum in upper secondary schools.
– teacher training.

From these local considerations, it is possible to obtain a picture that for some aspects (number of hours devoted to Earth Science and academic background of the teachers) can be generalised to the national context. Therefore, we believe that some actions need to be taken to respond to the teachers' requests and to address the critical issues in the teaching of Geosciences in school. In particular, authors are aware of the limited impact of the local sample which was explored; however the results which were obtained suggest the questionnaire design as suitable and effective in capturing the explored scenario. In this sense, projects aimed at defining regional and national samples are already running.

An important point to consider would be to organise the educational pathways of the Natural Science curriculum so as to take account the characteristics of the individual disciplines that make up the curriculum. To this end, it would be useful to divide them into two macro-areas, "Earth and Environmental Sciences" and "Life Sciences and Biotechnology", and to structure them according to their intra and interdisciplinary relationships. In addition, the verticality of scientific pathways between school and university should be highlighted with greater effectiveness. These revisions should be accompanied by a better organisation of the spaces and times devoted to Natural Sciences, and in particular to Geosciences, by providing the necessary tools and means for the effective implementation of the didactics of competence. These changes should lead to a new structuring of the Italian pedagogical school system, starting from the actual framework based on the didactic of competences. We hope that this change will be made after a broad public debate involving the school community, and that concrete guidelines will be set out on how the new structuring will be applied.

Another crucial issue, in order to make didactic action truly effective, is that a special attention should be paid to the training of teachers by seeing to all of its aspects and, above all, by focusing on the epistemological principles of the various disciplines of the Natural Sciences. In particular, this objective should mainly interest Earth Sciences, by extending the training offer, which is rather lacking in this field in Italy.

Finally, we believe that a teacher should have a consistent geological-epistemic background, didactic competences and a passion for Earth Sciences subjects in order to make the teaching-learning process in Geosciences meaningful and to promote student interest.

The ministerial reform of the Italian higher education system gave an answer to the need for renewal in the European and International context in the field of education. In our view, much has been done, but much remains to be done to fully achieve the goals set and to take advantage of teachers' human and intellectual potential, who are often not in the best conditions to fully express their professional potential.

ACKNOWLEDGMENTS

We would like to thank all the teachers who participated in the survey. We also thank the teachers who took part in the discussions on the didactic aspects of the survey and on the framework of the Italian school system for their helpful suggestions and comments. We are grateful to Maria Concetta Consentino and Maria Linda Tumbiolo, respectively President and Executive Committee member of Palermo Section of the Associazione Nazionale Insegnanti di Scienze Naturali (ANISN) for their support in distributing the questionnaire, and to Anthony Leone (Wall Street English of Palermo) for his help in the English revision of the paper. We are also grateful to the two anonymous Reviewers for their helpful and constructive comments and to prof. M.C. Salvatore for the revision of the figures, that improved the paper.

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(Ms. received 17 July 2024, accepted 16 October 2024)