

# SCIENCE EDUCATION IN ITALY: CRITICAL AND DESIRABLE ASPECTS OF LEARNING ENVIRONMENTS

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## Introduction

This study has been carried out in the context of the European project "Professional Reflection-Oriented Focus on Inquiry Learning and Education through Science" (PROFILES), in which Marche Polytechnic University is participating as the Italian partner.

Marche Polytechnic University (UNIVPM, Italy) is one of the partners of the European PROFILES project. PROFILES (Professional Reflection-Oriented Focus on Inquiry Learning and Education through Science) is funded by the Seventh Framework Programme of the European Commission (<http://www.profiles-project.eu/>) and involves 22 institutions from 21 different countries. The project promotes inquiry-based science education (IBSE) (Rocard et al., 2007; Bolte et al., 2011; Bolte, Holbrook & Rauch, 2012) and aims to increase teachers' competence and to enhance scientific literacy of students, encouraging new approaches in science teaching (Holbrook & Rannikmae, 2007; Marks & Eilks, 2009; Cavas, 2012). The task is to support teachers to create motivating learning environments.

Despite the importance of science education in the contemporary society, according to Schreiner and Sjøberg (2004, chap. 4.2), there is falling interest in science and technology in the way it is being taught and studied at school. In this regard, some interesting data about the state of science education in Europe can be found in "Science Education in Europe: Critical Reflections" (Osborne and Dillon, 2008). It has been affirmed that many high school students "have a perception of science education as irrelevant and difficult" (Rocard et al., 2007, p. 9).

It is necessary to act and change this perception, but the way forward is not clear yet (Cavas, 2012; Holbrook, 2014). Although there are positive examples of change, the teaching method in which an oral presentation is



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**Abstract.** *Science teaching plays an important role in the contemporary society, but nowadays, many high school students are often not interested in school science. The purpose of the study was to enhance the quality of teaching and to encourage learners to study science, making student learning more effective and meaningful. The opinions of different stakeholders was taken into account. In Italy, almost 200 participants, counting both teachers and students, answered a questionnaire concerning the following aspects of teaching and learning: situations, contexts, motives; basic concepts and topics; scientific fields and perspectives; qualification; methodical aspects. The results obtained showed the priorities and main gaps in current science education. In particular, scientific literacy should be essentially based on three concepts: the development of communication skills, the improvement of intellectual skills and the development of personality. Unfortunately the study has also highlighted that the approaches judged more effective are not really common in the current educational panorama.*

**Key words:** *inquiry-based science, learning environment, PROFILES project, science education.*

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exposed to learners is still considered the primary one; it is certainly convenient to present information to a large number of students, but it has the disadvantage to place students in a passive role. As has been rightly said, "using the material basis absence as an argument explaining the poor situation is not a serious statement." (Lamanauskas & Augiene, 2009, p. 102).

The efficacy of other new and more meaningful teaching methods (e.g., cooperative learning, problem solving) has been widely tried (Slavin, 1995; Felder & Brent, 2007; Hattie, 2012; Cardellini, 2014), but they are little applied. The result of this is that learning depends on communication skills of the teacher and lessons are often considered boring and even irrelevant by the learners. Many students are not able to apply critical thinking and therefore they cannot develop their decision-making abilities. These matters can be overcome through the practice of inquiry-based science education in which the students are encouraged to use inquiry skills. In fact, through the inquiry approach, the teacher can guide learners to ask questions, propose answers, make hypotheses and connections, interpret data and to present results. In this way, students can participate actively in the lesson. All these aspects are strongly supported by the PROFILES project, according to which students have to be involved in cognitive thinking processes, collaborative teamwork, gaining the range of scientific process skills, enhancing communication skills, and developing personal attitudes (Holbrook & Rannikmae, 2012).

In particular, PROFILES aims to motivate learning by promoting an "education through science" (Holbrook & Rannikmae, 2007; Marks & Eilks, 2009). This European project also supports the use of PARSEL-type modules ([www.PARSEL.eu](http://www.PARSEL.eu)) which are based on socio-scientific issues and encourage students to the use of critical thinking and reflection (Holbrook, 2008; Hofstein, Eilks & Bybee, 2011). The final purpose of PROFILES project is just to make the learning of science subjects more interesting, effective, meaningful and, furthermore, to "bridge the gap between the science education research community, science teachers and local actors" (<http://www.profiles-project.eu/>).

Since it is known from several studies (for example the OECD Programme for International Student Assessment, <http://www.oecd.org/pisa/>) that science education needs to be improved, a study aiming to identify the most important aspects and methodologies on which science education in Italy should be based has been carried out.

## Methodology of Research

### *General Characteristics of Research*

According to the aims set by PROFILES, it is very important to take into account the opinions of different stakeholders, which is any person or organization with an interest in education being offered in a school, such as students and their parents, school policy makers and politicians, teachers, science teacher trainers, science education researchers and scientists.

For this reason, all PROFILES partners have participated in a Study on Science Education, collecting and analyzing, in three rounds, their stakeholders' views and opinions about science (Bolte, 2008; Osborne, Ratcliffe, Collins, Millar & Duschl, 2003). The main purpose of this study is to answer the following question: "Which aspects of science education do you consider meaningful and pedagogically desirable for the individual in the society of today and in the near future?" (Schulte & Bolte, 2012, p. 44). A wide range of different stakeholders' opinions about the purpose and value of science education was collected. The aim was to evaluate and to bridge the gap between the desirable and current learning environments by taking into account different stakeholders' views. A similar study regarding what to teach at school regarding the nature of science and its social practices has been carried out by Osborne et al. (2003).

### *Participants*

The samples of stakeholders consist of the following four groups:

1. Students at school,
2. Scientists,
3. University students,
4. Science teachers.

Initially, in the 1st round, 927 participants were asked, both in digital and in printed format, to fill in a questionnaire concerning the following aspects of teaching and learning: (I) Situations, contexts, motives; (IIa) (basic) concepts and topics; (IIb) Scientific fields and perspectives; (III) Qualification; (IV) Methodical Aspects.



It was not easy to get the answers from participants. Although more than 900 stakeholders were involved, the final sample of the first round was composed of 173 research participants, divided as follows: 44 students at school; 59 university students; 28 science teachers; 42 scientists.

In the second and the third round, the same participants that took part in the first round were invited to answer additional questions for further assessment. Table 1 shows a comparison between the number of participants of the three different rounds.

**Table 1. Participants of the three rounds of the study.**

	Sample Structure				Total
	Students at school	University students	Science teachers	Scientists	
Number of participants round 1	44	59	28	42	173
Number of participants round 2	12	34	20	26	92
Number of participants round 3	4	16	25	27	72
Participation rate between rounds 1 and 2	27%	58%	71%	62%	53%
Participation rate between rounds 1 and 3	9%	27%	89%	64%	42%

An overall reduction (53%) in data can be noted between the first and the second round, which is even more pronounced in the third phase of the study (42%).

#### *Research Procedure and Data Analysis*

In the first round, participants answered the following three open questions:

- Which situations and motives can be taken as a reason and in which context should science-related themes be put in order to stimulate and further scientific educational processes?
- Which science-related contents, methods and themes should a (scientifically) educated person have dealt with intensively?
- Which form of availability, skills, and attitudes should the individual attain regarding contents, methods and themes that are considered as educationally relevant?

Participants were asked to formulate their statements in such a way that every answer contained three formal statement elements:

- 1) Statements about situations, contexts or motives where scientific literacy is useful;
- 2) Statements about fields of science that are considered significant and which the individual should have dealt with;
- 3) Statements about the qualifications that are to be attained.

Insights from the first round were analysed, and the participants' statements were classified according to a category system. Overall, 88 categories were established, and the relative frequencies of the categories were estimated.

In the second round, the previously identified categories were reported back to the same participants for further assessment and quantitative analyses. In particular, in the 1<sup>st</sup> part, the priority and realisation in the practice of each category have been evaluated, and the following questions were asked:

- Which priority should the respective aspects have in Italian science education (priority)?
- To what extent are the respective aspects implemented in current Italian science education (practice)?

These two questions have been answered, with reference to each category, according to a six-tier scale, ranging from 1 to 6 (1 = "very low priority"/"to a very low extent"; 2 = "low priority"/"to a low extent"; 3 = "rather low priority"/"to a rather low extent"; 4 = "rather high priority"/"to a rather high extent"; 5 = "high priority"/"to a high extent"; 6 = "very high priority"/"to a very high extent").

In the 2<sup>nd</sup> part of the second round, participants were also invited to combine the categories that were considered to be more important. Thanks to the support of the PROFILES project coordinator (Freie Universität



Berlin (FUB) – Germany), the combinations of categories were analysed by means of hierarchical cluster analyses (using the Ward method and squared Euclidian distance), and three concepts concerning different suggestions about desirable scientific literacy were identified. These concepts were assessed in the third and final round where participants were asked to code the priority of the three concepts and their implementation in practice following a six-tier scale ranging from 1 to 6, as done in the second round. In particular, the last part of the study mainly considers the following questions:

- Which priority regarding concepts of desirable science education can be identified in the participants' assessments?
- To what extent are the respective concepts of desirable science education realized in current science education practice?
- What kind of priority-practice differences can be identified in the participants' assessments?

The data were analysed by means of descriptive and variance analytical methods. In analysing the results, the Wilcoxon signed-rank test was applied to evaluate whether the assessments of the three concepts were statistically different. In Figure 1, the method of data collection used in the study is summarized.

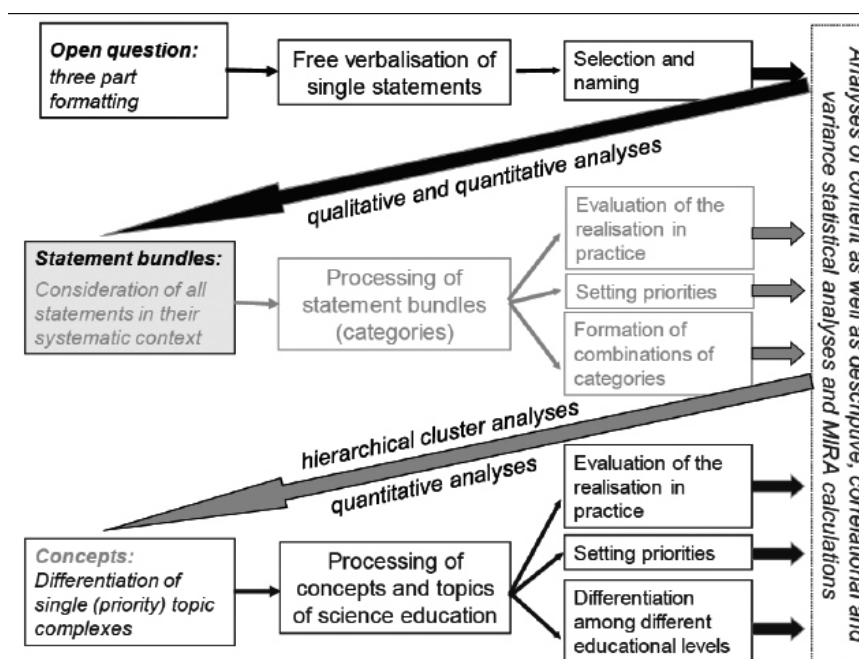


Figure 1: Method of data collection in the Study on Science Education (Bolte, 2008; Schulte & Bolte, 2012).

## Results of Research

From the first round, after collecting and analysing the stakeholders' answers, 88 categories regarding aspects of desirable science education were established. In particular, referring to the first issue, "situations, contexts, motives", 19 categories were found, while for the aspects, "(basic) concepts and topics" and the "scientific fields and perspectives", 24 and 18 categories were identified, respectively. With regard to the third aspect ("Qualification"), the participants provided 19 categories and, regarding the fourth issue, 8 Methodical Aspects were considered effective.

In Figures 2-6, with reference of each group of participants (students at school, university students, science teachers and scientists), the most frequently mentioned categories and their relative frequencies (RF) are shown. It can be seen that the highest relative frequencies are related to the aspect, "Situation, contexts, motives" (Figure 2). In particular, according to the participants' comments (both teachers and students), the experimental activity is judged as a priority; especially students at school consider experimental works, more than the other categories,



to be very useful as they involve students actively. All research participants acknowledge laboratory activity as an effective educational tool for helping learners to better understand phenomena and concepts.

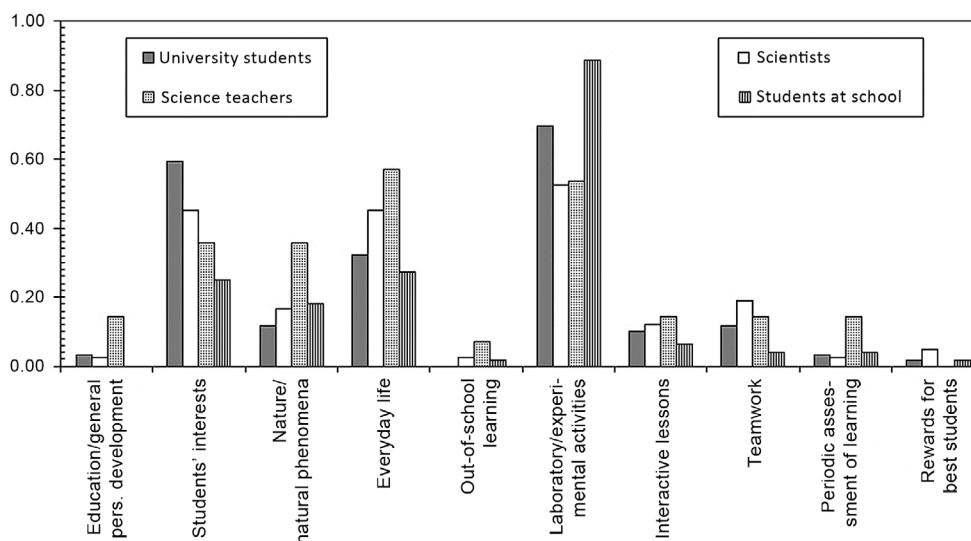
Science teachers consider important reflection, growth as development of critical thinking, student behavior and act responsibly (Figure 5). At the same time, students' interests, connections to everyday life and to natural phenomena, as well as teamwork appear to be helpful to stimulate students' curiosity in the educational process.

Regarding the other aspects of desirable science education, there is a greater dispersion of data. Indeed, the RF values are rather low ( $RF < 0.5$ ); see Figure 3-6. With reference to the aspect, "basic Concepts and topics" (Figure 3), it is of interest to note that the category judged most important is: "Matter in everyday life". This result is in accordance with the insights related to the aspect, "Situation, contexts, motives". In fact, it confirms the importance of dealing with topics that are familiar to students and connected to their living environments in order to enhance their interest and consequently to improve scientific literacy. This aspect of education is considered important in the philosophy of the PROFILES project (Holbrook & Rannikmae, 2014).

Scientists are in agreement with science teachers that both interdisciplinarity and history of science are important, while according to university students, science matters should be dealt with current scientific research and consequences of technology development, whereas students at school would like to study mainly human biology (Figure 4). The importance of the history of science is a surprising finding since it is something that is usually not very considered in textbooks.

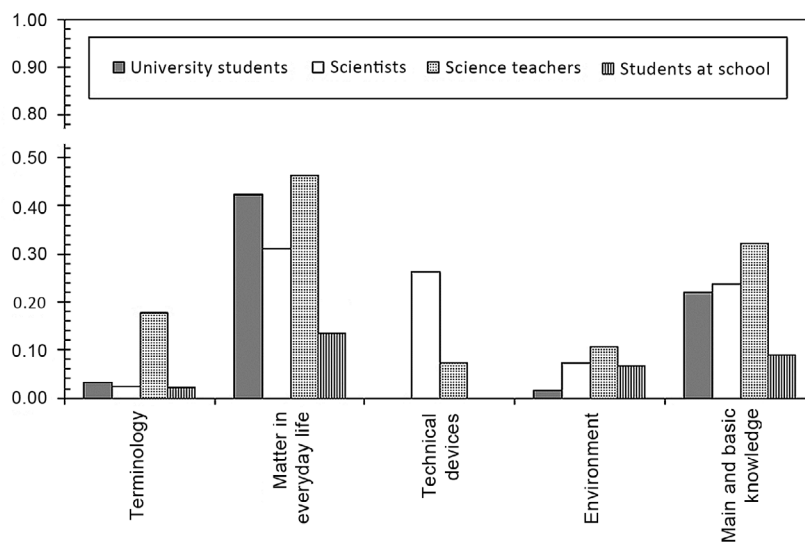
Concerning the qualification that students should develop, the participants gave several statements, and the opinions were rather heterogeneous. According to the responses provided by science teachers, scientists and university students, comprehension and understanding skills should certainly be improved, but while science teachers consider that students should also improve their capacity for reasoning, scientists think it is more important to capture the interest and curiosity of learners (Figure 5). The ability to perform experiments is judged particularly important by the students at school and, unexpectedly, these students do not consider social skills and teamwork as important.

Regarding the desirable methodical aspects (Figure 6), participants acknowledge that cooperative learning is surely a powerful teaching tool, because it involves students (who interact with each other) in order to achieve a common goal. Based mainly on the university students views, the discussions and debates also make the learning environment more meaningful.

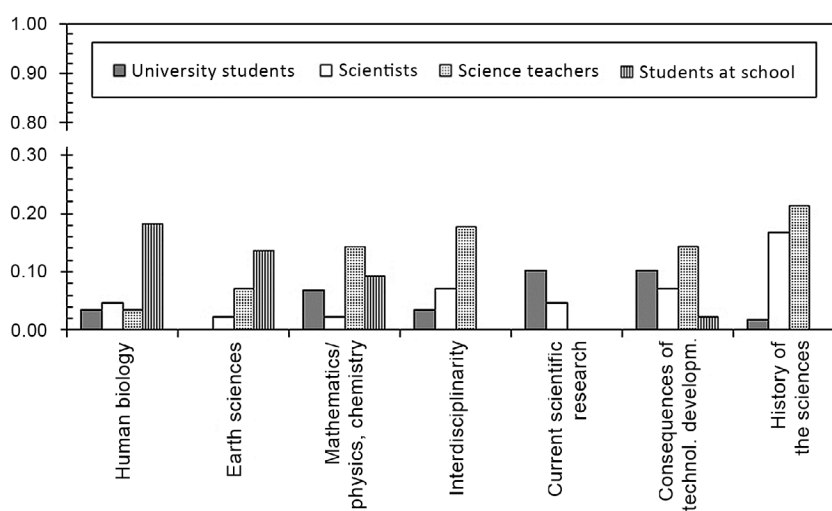


**Figure 2:** Relative frequency (RF) of the 10 most frequently cited categories regarding the aspect: situations, contexts, motives.





**Figure 3:** Relative frequency (RF) of the categories regarding the aspect (basic) concepts and topics (Cut-off point = 0.10).



**Figure 4:** Relative frequency (RF) of the categories regarding scientific fields and perspectives (Cut-off point = 0.10).



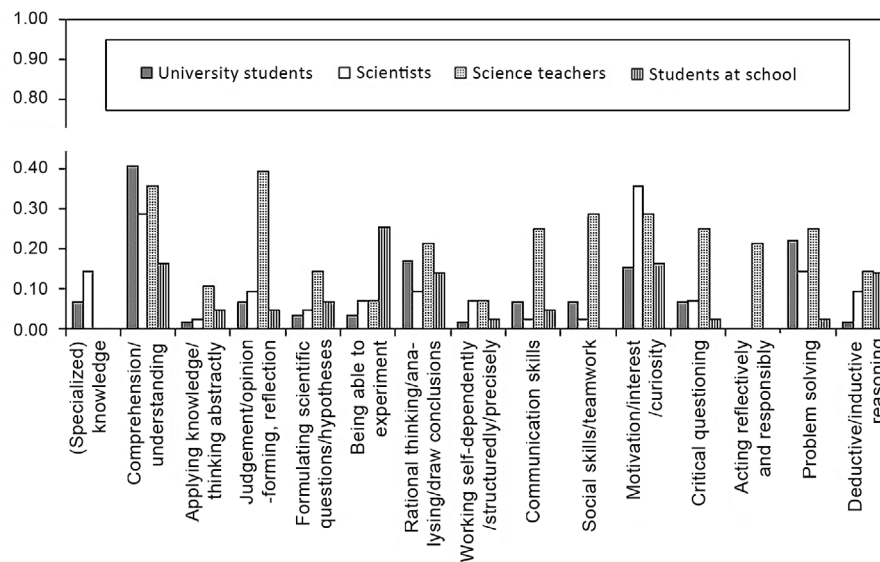


Figure 5: Relative frequency (RF) of the categories regarding the aspect “qualification” (Cut-off point = 0.10).

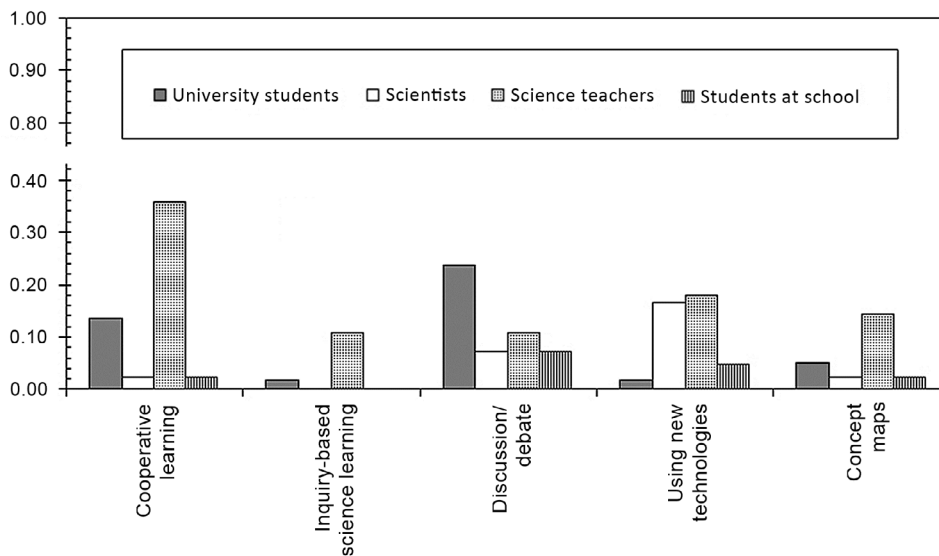


Figure 6: Relative frequency (RF) of the categories regarding methodical aspects (Cut-off point = 0.10).

Regarding the priority and practice of the identified categories, the most meaningful results were achieved for the aspect “Situation, context and motives”, and there seems to be a big gap between the priority and practice of the main categories of the desired science education. Indeed, with regard to the total sample, none of the five most important categories judged by the participants is sufficiently practiced in Italian schools, especially the



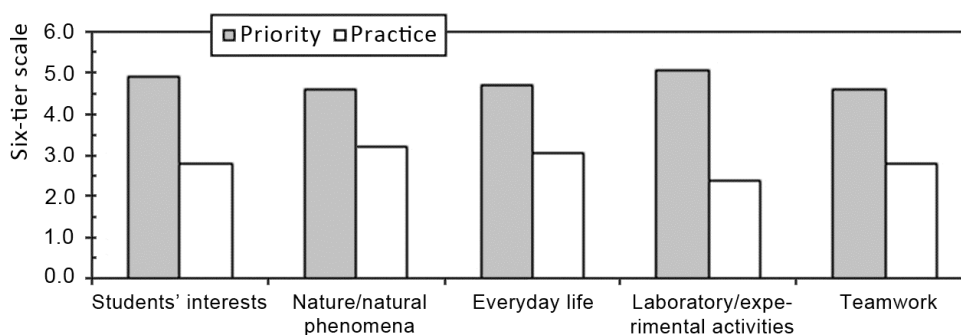
experimental activity, for which the priority assessment mean value is 5.1 (“high priority”), while the practice assessment mean value is 2.4 (“to a low extent”) (Figure 7).

From the combinations of the categories which are judged most important, the following three concepts concerning different suggestions about desirable scientific literacy were identified:

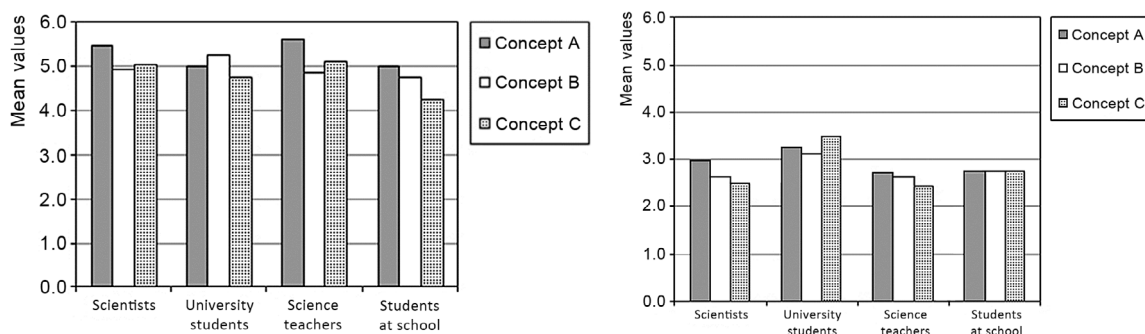
**Concept A:** relevant issues and motivations to improve learning, interaction among students and communication skills.

**Concept B:** intellectual development mainly related to the current scientific research, technical devices, occupation;

**Concept C:** general personality development through innovative methodical aspects (e.g., concept maps) which promote inquiry-based science learning.



**Figure 7:** Comparison between the priority and practice of the main categories related to the aspect, “Situation, contexts, motives”.



**Figure 8:** Mean values of the (a) priority and (b) practice assessment by the sub-sample groups.





**Table 2. Priority assessment by the sub-sample groups - mean values and significance test values (Wilcoxon signed-rank test).**

Educational level	Mean values			Significance value		
	Concept A: Relevant issues and motivations to improve learning, interaction among students and communication skills	Concept B: Intellectual development mainly related to current scientific research, technical devices, and occupation	Concept C: General personality development through innovative methodical aspects which promote inquiry-based science learning	A/B	A/C	B/C
Students at school	5.0	4.8	4.3	0.593	0.180	0.361
University students	5.0	5.3	4.8	0.345	0.374	0.066
Science teachers	5.6	4.8	5.1	0.001	0.016	0.339
Scientists	5.5	4.9	5.0	0.0124	0.058	0.673

**Table 3. Practice assessment by the sub-sample groups - mean values and significance test values (Wilcoxon signed-rank test).**

Educational level	Mean values			Significance value		
	Concept A: Relevant issues and motivations to improve learning, interaction among students and communication skills	Concept B: Intellectual development mainly related to current scientific research, technical devices, and occupation	Concept C: General personality development through innovative methodical aspects which promote inquiry-based science learning	A/B	A/C	B/C
Students at school	2.8	2.8	2.8	1.000	1.000	1.000
University students	3.3	3.1	3.5	0.647	0.441	0.154
Science teachers	2.7	2.6	2.4	0.698	0.136	0.408
Scientists	3.0	2.6	2.5	0.126	0.074	0.571

Figure 8 shows the results related to the general priority and practice assessments of the three concepts by the four sub-sample groups: Students at school, University students, Science teachers and Scientists. It can be seen that all three concepts are considered relevant and important in learning environments, as mean values of the priority assessment varies from 4 ("rather high") to 6 ("very high") (Table 2), but in the opinion of the participants none of the concepts are adequately practiced, as mean values of the practice assessment are rather low (Table 3). Furthermore, the Wilcoxon signed-rank test was applied for the following comparisons: Concept A/ Concept B (A/B), Concept A/Concept C (A/C), Concept B/Concept C (B/C). The results of the Wilcoxon test show that, in general, there are no statistically significant differences in the assessments of the three concepts, even though Concept A, supporting communication skills, is certainly considered very important, especially for science teachers (Table 2 and Table 3).

## Discussion

Research participants gave their opinions about aspects, pedagogically considered more relevant, on which science teaching should be based. The study highlighted that in Italian school students' interest should increase



since both motivation and determination play an important role in science education. The results obtained showed the main critical aspects which, based on the views of the stakeholders, cause declining interest in science education. Also, many useful suggestions and ideas were provided by the participants to make science learning more challenging and meaningful.

First of all, scientific literacy should be mainly based on:

- Experimental activity;
- Issues related to everyday life;
- Natural phenomena.

If properly guided by their teachers, learners will be able to develop theories in order to formulate hypotheses and explanations based on experimental evidence (Holbrook & Rannikmae, 2014). Students should not simply learn concepts through textbooks or frontal lessons, but they need to be involved in the building of their knowledge.

Then, once the student has acquired basic knowledge, they should be able to apply the knowledge acquired and be able to work and to perform experiments self-sufficiently and precisely. They should also be able to develop critical questioning. The extent of how much the inquiry should be guided is a matter debated in the literature (Kirschner, Sweller & Clark, 2006; Hmelo-Silver, Duncan & Chinn, 2007). In order to improve communication skills, encourage the curiosity of the students and support the development of emotional personality, teamwork, discussions and debates should be promoted. Teachers should have interactive lessons. All this requires a significant change in the way of teaching and a type of teacher with professional skills that allow her or him to adapt to the multiple educational preferences of students.

In this desirable change, the teacher plays a central role as highlighted by other studies: "The teacher encourages, accepts, trusts, respects, and otherwise demonstrates that he or she cares about students' emotional well-being. When their relationship with their teacher is emotionally supportive, students experience more enjoyment and interest in their schoolwork, have more positive self-concept and higher self-efficacy, are more likely to use self-regulatory strategies, and persevere in the face of difficulty and criticism." (Shernoff, 2013, pp. 152-153).

Also the methodological aspects are very important to improve the learning of science and inquiry-based learning. Using cooperative learning, concept maps or problem solving techniques, the personality and reasoning skills of the students are developed. Several studies have shown that, if correctly applied, cooperative learning encourages students to learn significantly more and better and allows them to have a deeper understanding (Slavin, 1995; Felder & Brent, 2007; Cardellini, 2014).

## Conclusions

The aim of this research was to obtain some insight into the direction required to make the necessary changes so as to make education more interesting and engaging for students. What kind of learning environment makes science learning more challenging and meaningful? Considering the complexity of the study, we expected various (and perhaps even contradictory) answers.

Several priorities regarding aspects of desirable science education were identified and to what extent the respective aspects are implemented in the current science educational practice were assessed. The results showed that scientific literacy should be based on different aspects such as the development of communication skills, the improvement of intellectual skills and the development of personality. The results highlighted a big gap between the importance and application of these aspects in Italian schools. Students' interest and motivation should be enhanced along with the experimental activity and connections to natural phenomena and everyday life. Also, teamwork plays a key role in students' engagement and should be more encouraged. These are ambitious goals and quite difficult to achieve.

The present study also highlighted many critical aspects of science teaching in Italian schools. Surely, teachers play a central role, and their enthusiasm is what makes the difference. Teachers can act as a barrier to any change initiative, or they can be the authors of effective teaching, motivating students to develop critical thinking. PROFILES project encourages the use of interesting teaching-learning materials which, starting from socio-scientific issues, make science education more popular and relevant and, therefore, increase students' intrinsic motivation (some teaching-learning materials developed by Italian teachers can be found at: <http://www.profiles.univpm.it/>).



For the most part, PROFILES project provides a philosophy: any improvement in teaching and learning comes through a professionally prepared teacher. This is the reason why the project supports a professional development program: several studies show that teaching methods, such as Cooperative Learning, Concept Maps and Problem Solving, provide considerable and significant improvement. This can be a path that can be taken to enhance scientific literacy.

Further studies are necessary to evaluate the efficacy of these changes and their impact on student learning, especially on those involved in the PROFILES project. Moreover, the desire to study and know the history of science is a surprising result. In fact, if this finding is confirmed, a revision of textbooks would be needed.

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