The soil in the classroom: a middle school case study

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ABSTRACT
The Earth sciences have a relevant role in building both scientific competences and citizenship skills; nevertheless, in Italian middle and high schools these are prevalently taught with a poorly effective transmissive approach. This work presents the results of a research carried out choosing the soil as a topic and a class of 11-12 years old pupils as target, aimed at exploring the effectiveness of laboratory-based teaching on the acquisition of permanent scientific competences and on the birth of an autonomous way of learning to learn. The teaching approach used well assessed didactic instruments such as the work group, the exercise book and the sharing of observations. The results show that most pupils were able to use the acquired scientific knowledges and skills in different situations and became more aware of their own learning.

KEYWORDS
Middle school, science learning, soil, geoscience

RÉSUMÉ
Malgré l'importance du rôle des sciences de la Terre pour construire des compétences scientifiques ainsi que citoyennes, l'école secondaire Italienne les enseigne surtout par une méthode transmissive et peu efficace. Ce travail montre les résultats d'une recherche réalisée en choisissant le sol comme sujet d'enseignement avec une classe d'élèves de 11-12 ans. Nous nous sommes demandé si un enseignement fondé sur les activités pratiques est efficace pour l'acquisition de compétences et pour la naissance d'une autonomie d'apprentissage. La méthode d'enseignement s'appuie sur des outils didactiques déjà éprouvés, comme le travail en groupe, le cahier d'exercices, la mise en commun des observations. Les résultats montrent que les élèves ont employé

leurs connaissances et habiletés scientifiques dans plusieurs situations et ils ont amélioré leur autonomie dans leurs apprentissages.

MOTS-CLÉS
École secondaire, apprentissage des sciences, sol, géosciences

INTRODUCTION

The instructional sequence that we describe in this paper is part of a wider research on geoscience education in school, included in the PhD program at the Department of Earth Science of the University of Pisa. This program takes into consideration the development and implementation of some science learning sequences in partnership with teachers of nursing, primary and middle schools. Such field of didactic research is slowly developing in the Italian academic community, taking into account that both the scientific literature as well as the teachers' field experiences agree in evidencing that the traditional teaching of science is not effective (Rocard et al., 2007).

THEORETICAL FRAMEWORK

To know the environment in which you live and the processes that led to its current configuration, and that continuously transform it over time, is a necessary condition to be able to take informed decisions as aware citizens, able -for example- to identify connections and relationships, as well as to acquire and interpret the information. In this context, Earth sciences could contribute to the building of the so-called citizenship skills.

Unfortunately, Earth sciences are taught – at least in Italian middle and high schools - using a 'top-down transmission' approach. This kind of teaching and learning approach focuses on memorizing rather than on understanding (Rocard et al., 2007); therefore, it often results in short term memorization of 'mile wide and inch deep' knowledge.

Research questions

Moving from these considerations, our research investigated if a different approach to Earth science topics could favour both the achievement of scientific competences and an aware learning approach. In particular, we aimed to explore the effects of a daily use of laboratory activities, associated to discussion and verbalization of the experiences and to a continuous use of the science exercise-book, on two learning outcomes:

(1) the acquisition of long-lasting scientific competences (children should be able to observe a phenomenon, to describe it, to face with a different, even if similar, phenomenon, to plan a strategy to study it, even at a distance of time from the end of the learning sequence). Observation is not a superficial exam and needs time to be performed. In an active observation, 'the observer is checking his perceptions against his expectations' (Driver, 1986); it is important that pupils are aware of what they are searching (Ausubel, Novak & Hanesian, 1978). The importance of verbalization and writing in science learning is emphasised by many authors (see e.g. Wallace et al., 2004), even if the daily practice of most science teachers in Italian schools usually neglects it. Finally, the very concept of "competence" implies that pupils are able to manage a task by using their previous experiences, knowledges and skills.

(2) The birth of an autonomous way of learning to learn (Biggs, 1985). Despite a wide literature on this matter, and the relevance which the European (European Council, 2006) and national education institutions (e.g. MIUR, 2012) give to the "learning to learn" competence, this concept is still far from to be clearly defined (Hoskins & Fredriksson, 2006), including cognitive, affective-motivational and metacognitive dimensions. A quite articulate description of this concept can be found in the recommendation on key competences for lifelong learning (European Council, 2006): "*'Learning to learn' is the ability to pursue and persist in learning, to organise one's own learning, including through effective management of time and information, both individually and in groups. This competence includes awareness of one's learning process and needs, identifying available opportunities, and the ability to overcome obstacles in order to learn successfully. This competence means gaining, processing and assimilating new knowledge and skills as well as seeking and making use of guidance. Learning to learn engages learners to build on prior learning and life experiences in order to use and apply knowledge and skills in a variety of contexts: at home, at work, in education and training. Motivation and confidence are crucial to an individual's competence*". Among the different aspects involved in this broad definition, we focused on 'awareness of one's learning process and needs'; in particular we searched for evidences that children were able to explain what they have learned and how they learnt it.

The chosen learning approach, that is building knowledge through making experiences and reflecting about those experiences, can be overall framed within the "constructivism" theory (e.g. Tobin & Tippins, 1993).

An inquiry-based learning sequence was planned, in which pupils had to face with an Earth science topic by hands-on activities and by shared discussions of their observations. In building the learning sequence, we focused on five points, hereafter briefly listed.

(1) *Query*. In science, the starting point should be a question which is considered interesting and valuable by the investigator. (2) *Observation*. It is not only the mere 'visualization' of a phenomenon, but it is an active process, which should start by the employing of our senses, and taking note of regularities, differences, similarities with other phenomena etc. (3) *Investigation*. To find an answer to the starting question, it is mandatory to perform some kind of 'experiment' to test one or more hypotheses. It is worth to note that the points (2) and (3) correspond to the single 'exploration phase' of IBSE (Anderson, 2002; Bybee et al., 2006; Minner, Levy & Century, 2010); for our research we decided to devote distinct moments to the exploration, both of them followed by discussion and written comments. (4) *Development*. To favour the learning process, it is important that pupils reflect on what they are doing, both individually and in group. In this phase, it is essential to check the written and oral production of the children, as 'alternative framework' to explain phenomena (Driver, 1986) could emerge. (5) *Evaluation*. It is the necessary revision of the starting ideas and hypothesis, and the sharing of conclusions, at the light of the new knowledge.

METHODOLOGICAL FRAMEWORK

The overview of the study

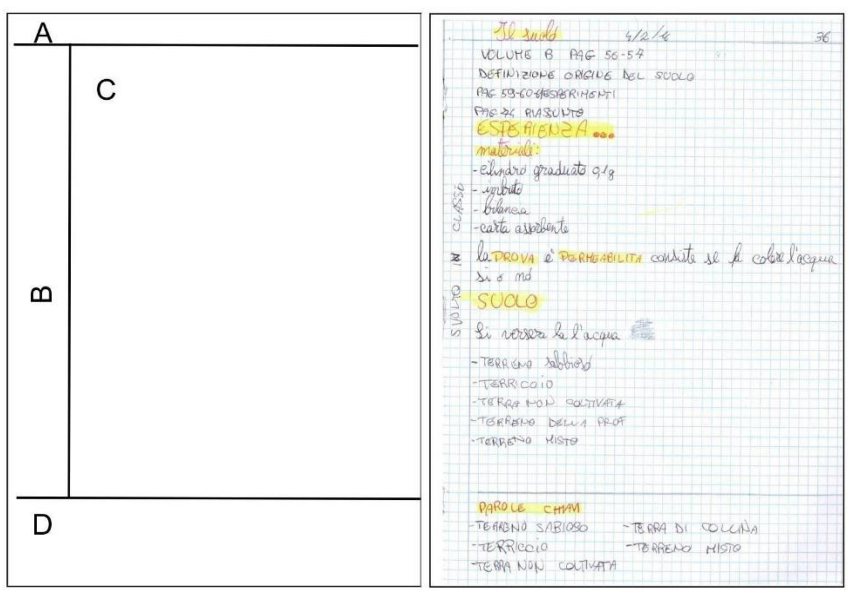
We selected a sample class at the first year of the middle school, that is exactly at the boundary between two different kinds of teaching and learning styles. We chose a relevant topic in geoscience within the curriculum, namely soil. Pupils have some naïve conceptions about the nature of soil, particularly as regards the presence of air, water and life (Brass & Duke, 1995; Helldén, 1995). It is worth to note that appreciating the complexity of the soil as an ecosystem may favour the responsible use of this not-renewable resource, contributing to form aware citizens (FAO, 2015).

The learning sequence was proposed to 23 pupils of the first class (11-12 years old) at the "I.C. Sacchetti" middle school in San Miniato (Pisa, Italy), in the school year 2015/16. The children were curious and collaborative, with a marked interest in science, but with no training in a laboratory approach in the scientific field. The teacher usually employs a well equipped classroom, specifically dedicated to the science teaching. She considers pupils' exercise-book as a fundamental educational tool, intended to favour the "learning to learn" process. From a week to the other, pupils have to elaborate a report about what happened in the classroom during the last lesson, by re-thinking and elaborating their own notes. The pages of exercise-book are divided in four parts to guide pupils' work, as shown in Figure 1.

Taking into account these features, tracing children's achievements and reasonings was carried out mainly through the examination of their exercise-books and, in general, of their written production.

In order to explore our research questions, the adopted methodology included:
(1) the planning of the learning sequence, giving relevance to the laboratory and to the use of the exercise-book, and including a final evaluation based on open questions;
(2) the assignment of a laboratory task, two months after the conclusion of the learning sequence;
(3) the request of a brief report about the topic. This assignment was requested approximately four months after the conclusion of the learning sequence.

FIGURE 1



Structure of the exercise-book (left) and example page right.
A=Topic, number of page.
B=Location (class, lab, home) and kind of work (homework, exercise, re-elaboration of classroom activities).
C=Description of activities. D=Free notes (keywords, comments)

Organization of the learning sequence

The learning sequence developed on six units, of two hours each, and a final evaluation.

The starting point was the question "what is the soil for you?". Pupils used indifferently the words "earth", "ground" or "terrain" in their explanation, and a lively discussion started about the meaning of the used words. The teacher moderated the discussion leading the class to reason about the significance of "ecosystem".

In the following lesson, the teacher divided the class in groups composed by four or five pupils, and gave them a kit including a hand lens, a magnet, tweezers, a ruler and different types of soil for free observation. Their observations and discoveries (presence of minerals, vegetables, tiny animals, moisture…) were collected and formalised at the beginning of the third unit, within a grid or template. Every child described in the exercise-book the observed soil specifying the finding locality, colour, smell, aspect, consistency, presence of animals and vegetable.

In the fourth lesson, pupils observed that bubbles escaped when water was poured into soil within a glass jar. They guessed that those were bubbles of the air which was contained within that soil. The teacher asked the pupils to close and shake the jar, mixing water and soil. Pupils noted that organic materials were kept afloat. The mixture was left at rest for a week.

In the following lesson, pupils first described the soil and water mixture. Then the teacher provided one beaker with 100 mL soil and one with 100 mL of water and asked the pupils to predict the final volume after mixing them. Some pupils hypothesized a final volume of less than 200 mL, suggesting that part of the water would have occupied the space between particles forming soil. After the experience pupils verified their hypothesis, obtaining approximately 160 mL of mixture.

In the last unit, pupils deepened their investigation of the soil-water system, and faced the concept of permeability. Each group worked with a different kind of soil. Pupils poured 100 mL of water on 100 g of soil, placed in a funnel lined with wet blotting paper. The funnel was placed above a graduated cylinder to evaluate the amount of water passed through the soil in a given time. The second experiment of the day was a simulation of a flood, pouring the same amount of water over three plastic containers with different types of soils, with and without grass. Pupils observed that different quantities of water escaped from the container holes and realized that the presence of vegetation greatly reduced the amount of soil particles taken away by water. In the last experiment the teacher weighed an amount of soil, put it over the radiator and weighed the soil after drying. By measuring the difference of weight, and recalling their previous observations about moisture in soil, pupils suggested the presence of water in the soil.

The learning sequence was monitored during its development through oral queries, controlling the exercise books, reading the homework. At the end, the teacher distributed a questionnaire with open questions about the soil as ecosystem, the general significance of the experience and their report about what they had learnt.

The laboratory task

Approximately two months after the end of the soil dedicated lessons the teacher consigned a clump of soil to each group of pupils, asking them to study it. No particular indication was given, but all the laboratory equipment was available for investigation.

Children reflections

As we were interested in medium and long-term effects of the described approach, we decided to collect the children opinions about the utility of laboratory and exercise-book in their experience of learning, not immediately after the learning sequences but after four months of school activity.

The question was "Did the activity with soil and the use of the exercise-book change your approach to new topics? If yes, how did it change?" and twelve pupils answered in written form.

RESULTS

The results of the analysis of the pupils' production (1) at the end of the learning sequence about soil, (2) after the laboratory task and (3) after four months are reported here below, with an attempt of quantification in terms of number of children who reached the achievements (use of scientific terms, acquisition of skills, conscious learning modality). In considering those numbers, we have to note that some lessons were attended by only 16 pupils. For the point (3) only qualitative results are available.

The examination of the pupils' answers immediately at the end of the learning sequence about soil gives the following results:

1) Twenty pupils out of twenty-three stated that soil is an ecosystem; two of them actually specified that soil is just the abiotic component of an ecosystem, being only its skeletal part.
2) Sixteen pupils reported the discovery of air in the soil. They described the phenomenon as air that flows in "channels" in the dirt or is located in tiny spaces between grains.
3) Ten pupils explicitly asserted they had learned what is the permeability and that it depends on the different kinds of soil.
4) Another surprising discovery for ten of the 23 pupils was the presence of water in all kinds of soil.
5) Six pupils stated that "the soil is made of layers". Actually, we do not know if this assertion arose from the observation of horizons in soil (for example in the textbook) or from the layers of particles with different grain size which sedimented in water jars during one of the experiments.

At the end of this experimental sequence, most of the pupils use scientific new words, such as "permeability" or "ecosystem", attributing to them a valid significance. Other scientific concepts, e.g. "porosity", are correctly described envisaging channels or spaces between grains, even if only few pupils use the specific term.

As regards the laboratory task, pupils correctly write their observations and independently plan to measure permeability and content of air through the laboratory experiences performed two months before. Ten out of sixteen pupils describe the sample of soil using the criteria of observation shared during the educational sequence.

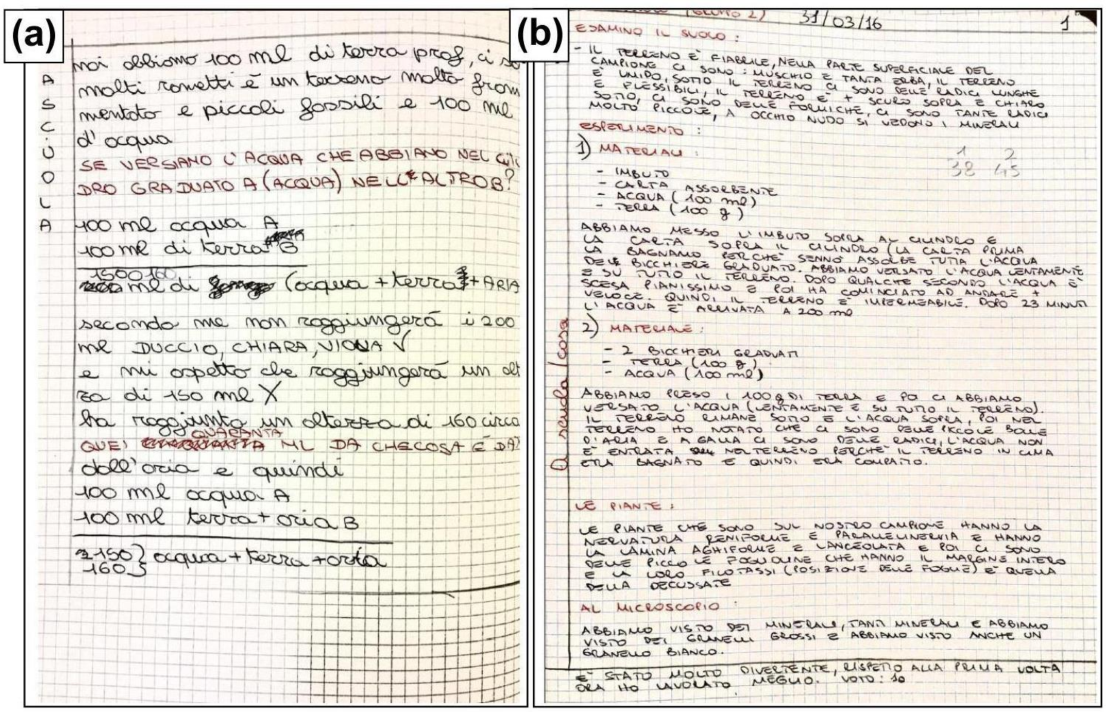
Eleven pupils out of sixteen correctly use all the fields in the pages of the exercise-book, with a significant improvement from the beginning of the sequence to the new laboratory task as you can see in the two examples of pages of exercise-books (Fig. 2).

Finally, as regards the thought of the pupils about their own learning process, most of the answers suggested a change of perspective from a "learn a learning strategy" attitude to being aware of and taking control of one's own learning (Biggs, 1985). Two out of 12 pupils simply list some learned information, one declares that her approach was not changed at all by the activities ("the soil activity did not change my way of studying because it was a topic like any other else"), whereas nine indicate a reflection about pupils' own learning and an awareness of a changed approach:

- "after the activity with soil I changed my approach to a new topic because I think about it",

- "The activity..... was useful because...... we had to understand what happened, and thus use our head".
- "The exercise-book organized in that way was useful to me for learning by understanding better, and not just by learning by heart".
- "experimenting about soil taught to me that information that I find in books have to be applied. Thus, when I find for example a formula in a maths book, I have to apply it by doing exercises".
- "I didn't know that the soil could hide all those information .... to use the exercise-book and to observe allowed me to note all steps and .... to understand what I have to do and what I did".
- "At the page bottom, by writing the keywords, it is very easy to learn the fundamental".
- "My approach changed because in the following activities I was able to examine soil by myself".

FIGURE 2



Example page of the exercise book in different moments of the learning sequence

DISCUSSION

The described learning sequence required a significant amount of time to the teachers and a constant and precise work. Anyway, the results indicate that this demanding work is effective in the learning process. Pupils show a different and better organization of their exercise books and, at least in part, of their own knowledge. The acquired scientific skills are revealed by the changed approach towards the observation and investigation processes, which are performed and described in a more systematic way, and confidently repeated in different occasions. The pupils themselves recognize that the exercise-book is a reference point in their learning. The learning process and the long or medium-term memorization is favoured by the experimental handling of soil, too. The memory of the active experiences, associated to verbalization, is less 'volatile' than the teacher words and those experiences are retained in the minds of pupils, so that they are able to recall them and use them even after a relatively long time.

Both the tools (laboratory approach and intensive use of the written elaboration) are probably responsible in making pupils aware of their own learning, namely "learning by understanding better, and not just learning by heart", to use the words of one of the pupils. This sentence and similar others indicate an attempt of meta-cognitive thinking about their personal attitude towards learning.

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